A study of how children, aged 10-11 years engage in decision making activities in science, with a focus on the quality of argumentation, the use of evidence and the social dynamics of group work

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A study of how children aged ten to eleven years old engage in decision-making activities in science, with a focus on the quality of argumentation, the use of evidence and the social dynamics of group work.

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Abstract

The thesis reports a study undertaken into the development of children's scientific thinking, in particular, how children aged 10 - 11 years respond to and use evidence in reaching decisions. As concerns are being raised about people's lack of decision-making skills, especially when dealing with scientific or socio-scientific issues, the skill of using evidence is becoming increasingly more important. The role science education has to play in the development of these skills is explored with specific reference to primary school education.

Research into children's argumentation skills is a relatively new field of exploration and so activities were designed specifically to enable data to be gathered on how children used evidence to make decisions as individuals and in small groups. The thesis reports on the theoretical frameworks that underpin both the development of the research methods and the analytical techniques used in the research.

The research has involved three different primary schools and twenty children working in groups of four. The children's discussions, taped and transcribed, showed a variation in success with which children construct scientific arguments; some groups debate most of the evidence, whilst others explore a limited range of options. Levels of argumentation skills are identified for the groups of children to show the range of abilities of children in Year 6 classes. A case is then made for the need to develop children's argumentation skills in the primary school through science activities where children have to evaluate evidence to draw conclusions and make decisions.

Further exploration of the data show that children adopt different roles in the discussions and that these roles have an important influence on how evidence is used. It is argued that more research needs to be done on the roles children prefer so that teachers can plan the composition of groups more effectively in the classroom.

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Contents

Page

Chapter 6. The development of the analysis techniques

Chapter 7. The findings: how children use evidence in discussions

Chapter 9. Conclusion

Tables

Figures

Charts

Chapter 1 Children using evidence in science

1.0 Introduction

This study has emerged from a belief that there is insufficient emphasis devoted to the development of the skills of interpreting and evaluating evidence in science education. These skills are necessary for children to be able to explain their ideas about events and phenomena; skills that primary school children are expected to learn (DfES 1998).

Through decision-making activities in science, children can learn how to evaluate evidence in order to see what possible choices can be made, whether the evidence is sufficient to justify a particular conclusion and how the evidence can support the rejection of alternative conclusions.

Examination of the current science and citizenship curricula indicates that there is some confusion about the capabilities of primary school children to use evidence to justify their reasoning. So it is important to establish what skills children demonstrate when engaged in decision-making activities. The main aim of this study is to examine the skills children, aged ten to eleven years old, use when making use of evidence in decision-making in science, both in groups and as individuals.

The purpose of this chapter is to set the context for the study by explaining the key questions and main aims of this research. It clarifies why this topic is so important, to teachers, to schools and also of concern to society. It is proposed that it is crucial to develop children's skills in using evidence so they will be able to function as informed, critical and responsible citizens in the future, and that the development of such skills should begin at an early age.

As there has been little research in this field, techniques to analyse the data have been designed, some drawing on existing analytical techniques and others developed specifically for this research. These techniques also make a contribution to the field of research into children's use of evidence and argumentation skills, as they illuminate how such skills can be assessed.

1.1 The research questions

This research is concerned with children's abilities to use and evaluate evidence when making decisions in science. The research aims to clarify *how* children use evidence in decision-making activities and *whether* they use the evidence to justify their decisions. The two key questions are therefore:

1. **How do children make use of evidence to justify the decisions they take when they work in a *group*?**
2. **How do they make use of evidence to justify the decisions they take when working as *individuals*?**

The context of the research in science education is important for three main reasons. First, the science curriculum identifies that children should be taught skills, such as the consideration and evaluation of evidence to draw conclusions, through investigations (DfEE 1999b). Second, many controversial issues relate to socio-scientific issues and decisions made by individuals and groups will require some scientific understanding. Third, the skills of using evidence and argumentation are needed in any aspect of decision-making in life and discussion and arguing are parts of the way of doing science (Watson et al. 2004).

1.2 The main findings of the research

The findings indicate that children, aged ten to eleven years old, are capable of using evidence to support their claims and they are capable of sustained argumentation when they work in groups on decision-making activities. However, the findings show that not all children demonstrate the same level of skill and that there are considerable differences between the skills of children of the same age.

The results show that differences in the way children use evidence are partly due to the nature of activity undertaken but that the nature of the group has a greater influence on the way evidence is used. These findings suggest that the abilities of children to make use of evidence and engage in argumentation are related to their levels of ability; high achievers appearing to have more sophisticated argumentation skills. However, the findings also suggest that the development of children's skills might also be related to the teaching strategies adopted by their teachers. Teachers who expect children to justify their decisions and provide evidence to support their claims may promote children's skills in argumentation.

An unanticipated finding was the similarity between the roles children play in group work and the roles adults play in team work. This aspect of the research has drawn on the field of management studies (Belbin 1981; Margerison and McCann 1990) to understand how the roles adopted affect the way children make use of evidence. The findings indicate that there are specific roles influencing the way children make use of evidence, and the process of argumentation within a group. The findings, therefore, have implications for current pedagogical practice and the way teachers organise groups in the classroom.

1.3 The importance of the research topic to education

The way children engage in discussion and use evidence in decision-making activities in science is an important topic for two main reasons. First, education needs to develop the skills required for decision-making particularly, about socio-scientific issues, as these are the type of issues that will continue to face society in the future (Ratcliffe and Grace 2003). Second, in making decisions people engage in a process of argumentation that utilises and develops their scientific conceptual understanding. It is through talking to each other that people engage in a process of 'meaning-making', whereby they come to an understanding of the scientific view for themselves (Mortimer and Scott 2003). These reasons will now be explored in more detail.

1.3.1 Developing decision-making skills through discussion

Contemporary science raises issues whose solution requires careful consideration of ethical and moral issues (Osborne 2000) and so children need to be prepared to meet the challenges of, and engage in debate about, issues posed by future scientific and technological advances. To do this, schools need to present children with decision-making tasks for which there is no one fixed viewpoint and no obvious answers. They need to be able to appreciate the strengths and weaknesses of different sources of evidence, to make a sensible assessment of risk and to be able to recognise the implications of their choice (Millar and Osborne 1998).

As adults of the future, children are likely to be faced with even more complex decisions and they need to be empowered to be able to take part in effective decision-making. In order that teachers can judge whether their pupils are developing skills of interpretation and evaluation of evidence, they need to have a sense of the level of skills which pupils are capable. Teaches also need to know what factors might influence the development of these skills. This research sets out to address these points.

1.3.2 Developing scientific understanding through argumentation

Arguments amongst scientists have led to the advancement in scientific understanding as they challenge and oppose each other's methods and interpretations before agreements are reached. Children can also advance their own scientific thinking through talk, as they have to articulate their ideas and reflect on the views of others (Mercer 2000). Children need to be taught the skills of argumentation so they can appreciate the consequences of alternate views, can comprehend the significance of hypotheses and can put forward evidence that defends their position. This research aims to find out the capabilities of children, aged ten to eleven years old, in the way they make use of evidence to defend their claims and decisions.

1.4 Primary education

For students to fully develop their decision-making skills they need to be taught skills of argumentation in a more systematic way, and they need to have the opportunities to discuss controversial issues from an early age. As stated previously, science education offers the opportunity to develop argumentation skills, in particular, the children's ability to consider and evaluate evidence. Such skills occur in the science National Curriculum from Key Stage 1 (ages five to seven). However, for teachers to plan for progression in these skills more needs to be known about the capabilities of young children. This research is concerned with identifying the skills of the evaluation of evidence and the skills of argumentation of primary school children in Year 6 (aged ten to eleven years old).

Another reason the research was based in the primary age range was that my teaching experience was mainly in secondary schools and so I approached the research with an open mind about what the findings might show. I had no 'preordained ways of seeing things' (Denscombe 2003: 112) and wanted to discover new information in this area of research. The reasons why I chose to research the topic of children's use of evidence in decision-making activities will now be explained.

1.5 My interest in the topic

My interest and engagement with this topic has emerged from two areas of my work in Higher Education. The first came from my own experience whilst working to support student teachers with their planning of science lessons; it became evident that there was an insufficient emphasis devoted to the skills necessary to interpret and evaluate evidence. Much of the practical work was confirmatory in nature, producing data that did not challenge the children's ideas or encourage them to question their evidence.

Second, when I was working with practising teachers on how to approach the teaching of ethical issues in science, I was intrigued to read of the Wellcome Trust's move from the promotion of the public understanding of science to the promotion of public discussion (Smaje 1998). The Wellcome Trust had just invested £15 million to stimulate the debate about the ethical issues raised by developments in medical research, rather than concentrating on improving the public's understanding of science. The Trust's report on the 'Public Perspective of Human Cloning' emphasises the need to consult the public on scientific and ethical issues, but suggests that the public mistrust in scientific endeavour is a major barrier to a better dialogue (The Wellcome Trust: Medicine in Society Programme 1998). The requirement has changed from purely a need to understand the scientific knowledge itself to a need to understand how to debate the issues raised by this scientific knowledge. This change in emphasis, from educating the public to understand scientific knowledge to being able to engage in debate about scientific issues, is also relevant to school education.

Yet, the science curriculum is not effective in preparing children to make sensible decisions about science-related issues. The curriculum is perceived as overloaded, and pressures on teachers to complete the schemes of work has resulted in the teachers believing that they are forced to cut corners in the way they work (Turner 2000). Thus, the opportunity to explore scientific ideas and develop children's understanding is sacrificed because of the need to complete the syllabus.

Harlen (1999) argues that although science education has a dual role in providing an education for future scientists and for future citizens, the emphasis has been on the former role and certainly the statutory assessment of science education appears to support this view. Harlen makes the case for paying more attention to the second role and this has important implications for teachers of science. Most of our pupils will not be scientists; yet, the teaching of science in schools is driven by the needs of the minority who are going to follow a career in science. Although the assessment of the National Curriculum is still largely concerned with testing subject knowledge, with increasing technological advance, our society needs fewer and fewer individuals with scientific knowledge (Osborne 1998). We competently use technical equipment that few people understand either, how the pieces of equipment work or, how to repair them when they fail. There is no need to know how a mobile phone works as long as you know which buttons to press to receive a call or send a text message.

Teachers may not be able to change the content of the curriculum, but they can aim to teach in a way that makes children's science education more relevant to them in the future. They can do this by developing the skills of children that will enable them to cope with the tentative nature of scientific knowledge, rather than just the established science presented in most textbooks (Zimmerman et al. 2000). By doing so, children will be better prepared to engage in debate about the scientific issues that will affect them as the adults of the future.

1.6 The research context

Science education has a crucial role in developing people's abilities to engage in debate about ethical issues and the science curriculum should reflect this need. To take part in discussions about scientific issues, children need to be able to reason, to evaluate alternatives and to weigh up evidence competently. Siegel considers that one way of developing such skills is through argumentation because:

> Argumentation - whatever else it may be - is aimed at the rational resolution of questions, issues and disputes.
>
> (Siegel 1995: 162)

Surely science education is also aimed at these issues? Yet, the science taught in schools has paid little attention to the development of the pupils' skills of argument (Driver et al. 2000). Indeed, if we accept that the consideration and evaluation of evidence is core to the practice and learning of science, then it becomes clear that science provides an excellent opportunity for promoting such skills in children. Despite the emphasis on Experimental and Investigative Science within the science National Curriculum (DfE 1995), research suggests that little attention is given to children's critical evaluation of evidence and interpretation of its potential meaning. Such competences are essential skills (Watson et al. 1999) if children are to develop the ability to understand and participate in an informed debate about contemporary scientific issues.

From my own experiences in the teaching of science in secondary schools, it can be shown that pupils are capable of debating socio-scientific issues. These skills were evident when, for example, I had used some of the Science and Technology in Society materials (SATIS 1993) with my classes. In these activities the pupils had provided reasons for the decision they had made; they had listened to other pupils' points of view and had been prepared to change their minds. However, what was assessed in these activities was not how the children argued the issues but whether the scientific information they used was accurate. For example, one of the exercises involved the pupils in deciding where alternative energy resources should be sited. They had to choose where to place wind farms, solar panels and nuclear power plants in an imaginary town. The conversations that ensued indicated that the children engaged in debate and considered the possible effects on different groups of people. However, the assessment of the task took no account of how the decisions were reached; judgements were only made about the suitability of the proposed sites of the wind farms and solar panels made by the pupils. Watson et al. (2004) have also found that when students carry out scientific inquiries as a group, it is the written product that is assessed and assessment of the discussion and argument is often neglected. Without knowing how the children developed their arguments it is difficult to see how recommendations for improvement in their argumentation skills can be made.

As a response designed to understand these issues, this research set out to find out how children explore evidence when arguing about scientific and socio-scientific issues and whether they used evidence to support and justify their choices. The sources of evidence used by the children were identified to show whether they referred to evidence other than that which was provided. The research was designed to find out how children approached decision-making activities and whether the way evidence was presented affected the way children made use of evidence.

1.7 Design of analytical techniques

The analysis of the data required new techniques to be developed and these techniques could be used for further research in the field. For example, a schema, termed a discussion map, was developed to identify children's increasing sophistication in argumentation. These maps have been used to analyses the children's discussion in detail to show how evidence is used in the process of argumentation. As results of the analysis, levels of argumentation have been identified which teachers could use to assess children's development of these skills.

1.8 Thesis organisation

This chapter has introduced the research questions and has justified their importance in the context of science education for the adults of the future. The literature review provides the theoretical background for the research and has been divided into three chapters. The three areas concern:

- the need to improve people's skills of argumentation and use of evidence;

- the place science education has in the development of these skills;
- the opportunities in primary science for developing young children's skills of argumentation and the way they use evidence to make decisions.

Chapter 2 explores the literature to assess how appropriate the current science curriculum is for meeting these needs of our future citizens. Criticisms are made of the current provision for the curriculum's emphasis on content that does not reflect the needs and interests of children living in an age of constant scientific advance.

Chapter 3 establishes that the curriculum needs to develop children's abilities to think critically and to reason in order that they can cope with decisions posed by these scientific advances. It suggests that aspects of these skills can be developed through the skills of argumentation. The relationship between argument and thinking is explored and the contribution science education can make to improve the skills of argument is then considered. The current initiatives to develop argumentation in schools are then summarised and questions are raised about why so few of these projects are in the primary age range.

The purpose of **Chapter 4** is to provide an overview of the teaching of science in primary schools over the last 20 years. It describes the positive effects of the introduction of primary science part of the curriculum in England and Wales following the implementation of the Education Reform Act (DES 1988). It then indicates where primary science has the opportunity to develop children's skills of argumentation and justifies the age group chosen for the research.

Chapter 5 explains how the research questions have been extended in the light of the discussions in the previous chapters. Both qualitative and quantitative approaches were adopted in this research and the use of these two approaches is justified with reference to the literature on research design. The procedures of the pilot study are documented to show how its findings were used to inform the research methods used in the main study. Details of the four activities used with children in the main study are given along with the practical techniques used in gathering the data.

In **Chapter 6** details of how the data were prepared for analysis are given and then the analytical framework for the analysis is introduced. The parameters selected to analyse the data are explained and the coding schemes designed for each of these parameters are established. The findings of the data analysis are reported in the next two chapters. The first concerns the way children use the evidence in the decision-making activities; the second relates to the roles children adopt in the discussions.

Chapter 7 examines the findings of the data analysis and includes extracts from the data to illustrate how these findings were derived. These findings are discussed to highlight the key points concerning the way children make use of evidence as individuals and in groups. A consistency in approach to argumentation was shown by most of the children and the findings indicate that children, aged ten to eleven years old, demonstrate a range of skills in using and evaluating evidence and also their argumentation skills are at different levels to each other.

The focus of **Chapter 8** is the data analysis that had not been anticipated at the outset of the research. The findings, described in chapter 7, indicated that the social dynamics of a group impact on the way the children use evidence and on the quality of their argumentation. How this factor emerged from the data is revealed and the method for identifying the roles children adopt in group discussions is explained. The findings from the analysis are then discussed.

The final conclusions to the research are considered in **Chapter 9**. The implications of the findings for future practice in primary science teaching are identified and aspects for future research are suggested.

Chapter 2 Science education and the needs of future citizens

2.0 Introduction

This chapter is concerned with doubts about how well science education currently prepares children to be well-informed citizens, capable of taking part in debate about the socio-scientific issues with which they will be faced in the future. These doubts are well established in the literature.

The frenetic pace of change, particularly in the field of biotechnology, has meant that citizens in their daily lives are confronted with 'frontier science'- science as it is being discovered - and as a consequence need to be better prepared for controversy and disagreement amongst scientists. It is shown that in the 1980s policy makers thought that the public needed to be better educated about science so that they could take part in debate about scientific issues. Now, however, it is clear that the understanding of science on its own is not enough for citizens to be effective in decision-making. The implications of this change in perception are then explored.

The chapter includes discussion about the mistrust the public have of scientists and how this lack of trust impinges on their ability to make judgements about the different, and possibly conflicting, scientific evidence presented to them. Suggestions are made as to why this distrust has come about and what needs to be done to address this situation. The proposition is put forward that future citizens need to be better prepared in decision-making skills and, in particular, how to think and reason about scientific issues. The part science education currently plays in developing these skills is criticised and implications for change in the curriculum are reviewed in terms of both its content and the way science is taught in the classroom.

The conclusion of the chapter is that the current situation is unsatisfactory and science education needs to play a greater role in preparing citizens by equipping them not only with scientific knowledge but also with skills that enable them to make rational decisions about future scientific issues. In particular, people need to be better prepared to cope with the uncertainty of new scientific knowledge.

2.1 Social awareness of scientific issues

In contemporary society, citizens are confronted with a range of scientific issues that require them to make choices, either about personal actions or about policy decisions affecting the community at large. Choices that must be made by individuals include whether to eat genetically modified food or to vaccinate children against measles; other choices are less direct, but are expected from us as citizens as part of our contributions to wider policy-making, for example, where to locate mobile telephone masts.

Citizens have always had to make decisions, but in the modern world, scientific developments occur at a rapid pace and technological advances are made public very quickly. As a result people are forming opinions and making decisions about issues that are often new and inherently difficult to understand. For example, if the significance of altering the genetic code of body cells as opposed to stem cells is not understood it would be difficult for people to form a scientifically well-founded opinion about whether we should have stem cell research. Some developments in modern medicine advance so quickly that people are having to form opinions based on evidence as it initially emerges and is open to interpretation. However, citizens often assume that science is based on reliable objective knowledge (Mannion et al. 2003) and expect scientists to be able to provide definite answers to such questions as 'Are mobile phones safe?' or ' Is global warming a result of human activity?' As a result of this expectation, people may be unable to cope with uncertainty and react accordingly as they have done to developments with cloning, a reaction

Smaje (1998) describes as bordering on the hysterical. This lack of ability to consider issues rationally means that proper debate about such issues has been stifled and there are growing concerns about how citizens can be prepared to play an active role in personal and policy decision-making (Burden 1998).

The public understanding of science came under scrutiny at the same time as issues concerning a safer environment, conservation and the reduction of energy consumption became leading political issues (Porritt 1987, Solomon 1990). In 1989, the government of the day fared badly in the elections for the European Parliament where many of the political arguments centred on 'Green' issues. The then Secretary of State for the Environment attributed the failure at the polls to a lack of 'correct' information to guide the public's knowledge and understanding (Solomon 1990).

2.2 Public involvement in decision-making

People need to be equipped not only to make decisions about themselves and their families but also to play a wider role in policy formulation. Public participation is, in fact, increasingly considered to be an essential part of policy-making (Joss and Durant 1995, Hisschemolleer and Midden 1999). There are many different initiatives being carried out across Europe and other parts of the industrialised world that involve an increasingly public participation in scientific and technological debate. For example, in Denmark a consensus conference model has been introduced with scenario workshops and citizens' juries (or *Plannungszellen*). Scenario workshops, organised by the Danish Board of Technology, involve citizens in considering issues concerning society's use and regulation of technology and aim to feed the results of the workshop into local political debate (Anderson and Jager 2001). Unfortunately, if schools do not produce citizens who can think rationally, critically and creatively (Burden 1998), then the public's effectiveness in this decision-making role is questionable. If this situation is to be changed it is important that people's decision-making skills are developed.

Encouragingly, there are now movements to prepare young people to take part in decision-making, as can be seen by the Youth Parliaments currently being developed in the UK. For example, the 'Young People's Parliament, Birmingham' (YPP), gives children in the West Midlands a voice on local and global issues. In 2002, the YPP hosted a conference founded on the idea that young people need to be active participants in decisions that affect the future of the planet, especially where issues concerning food production around the world were debated. Another move to inform young people's engagement in debate is a website, organised by the Department for the Environment, Food and Rural Affairs (Defra), called 'youngGov': (http://younggov.ukonline.gov.uk/oee/youth.nsf/sections/homepage/$file/home.htn). The website is devoted to 11-18 year olds and gives information on issues that concern young people and details on how governments work. The aim of the website is to give young people a chance to 'have their say'. The website content indicates that many of the issues that matter to young people today are scientific in nature, such as environmental issues of pollution, recycling of waste, and the use of pesticides. There is clearly a role for science education in preparing young people to make an informed contribution to the debate on such issues.

The idea that education has a role to play in preparing people to engage in debate about scientific issues is not new. In 1985, the Royal Society set up a working party to look at the public's lack of scientific knowledge and limited ability to make judgements about scientific problems. As a result of the findings, published in the 'Bodmer Report' (Bodmer 1985), ways of improving the public understanding of science were developed. For example, the Committee on the Public Understanding of Science (COPUS) was established to make information on scientific advances more accessible to non-scientists (www.copus.org.uk/about_history). However, the focus at the time was mainly on improving the public's understanding of scientific knowledge of future citizens rather than involving them in the decision-making process.

2.3 Public understanding of science

Educating the public about science knowledge is not sufficient to enable them to debate scientific issues effectively. Instead, there is an increased awareness of the need to educate people in the skills of debate (Advisory Group on Citizenship 1998). The main role of the Communication and Education Department in the Wellcome Centre for Medical Science used to be the promotion of the public understanding of science. This aim was based on the premise that understanding the science behind biomedical advances would enable people to engage in informed debate about the social effects of such advances on society. However, this aim has not been realised and so the new focus of the department has shifted to the promotion of 'public discussion' (Smaje 1998).

The ability of people to take part in public discussion is essential in a society that expects its citizens to take some responsibility in making decisions that have a scientific basis. An explanation for why even an improved understanding of science has not resulted in the development of people's decision-making skills has been suggested by Fuller (1997). He believes that what non-scientists need to know in order to make informed decisions about science falls under the 'rubric of history, philosophy, and sociology of science, rather than the technical content of scientific subjects.' (Fuller 1997: 10). Fuller points out that many of the judgements we make about the validity and relevance of scientific knowledge are made without a deep understanding of the science.

Future citizens have to be able to take a responsible role in an unpredictable society and therefore need to be equipped with the necessary skills. There is a tension between science education that traditionally focuses on teaching children about established knowledge perceived as certain and new science issues in the public eye that are hotly debated and often profoundly uncertain. Perhaps the contrast between the teaching of science and the nature of contemporary scientific issues could result in the mistrust of scientists working in these areas.

2.4 Public disillusion with science

If the case has been made that science education has not prepared people for the role they increasingly need to play in society, the question arises as to what skills are needed. Many of the scientific issues under debate are contentious and are likely to involve disagreement amongst the scientists themselves, so people will need to know how to weigh up the scientific evidence associated with the alternative views of scientists. Yet, people have become disillusioned with science (Reiss 2000) and the public's faith in the expertise of science has, as Osborne (2000) explains, been damaged by a number of high-profile failures such as the BSE debacle and the Chernobyl disaster. The Wellcome Trust said in its research into the public perspectives on human cloning report said:

> A striking theme found throughout the research was the lack of trust that participants expressed in scientists and those perceived to be in control of scientific research.
> (The Wellcome Trust: Medicine in Society Programme 1998: 43)

Klotzko, a bioethicist, reports that the level of distrust in scientists in the UK is as 'stunning as it is unwarranted' (Klotzko 2003: 34). If people simply dismiss the claims of scientists when there is disagreement then public debate on the issue will be impossible. Therefore, for genuine discussion to take place it is essential that education instils a respect of alternative views.

When planning how to educate our future citizens, it is useful to consider how this lack of trust in science and scientists has come about. Three possible causes for the lack of trust are now proposed and the significance of each one is explained below. The key issues are that people:

- do not understand some of the scientific issues (unsurprising given the breadth of science and the rapid rate of advance);
- perceive that some scientific advances cause unexpected and unwelcome problems;
- cannot deal with conflicting evidence from scientists.

2.4.1 Understanding of scientific issues

As previously mentioned, people find it difficult to understand the science behind many advances and become confused about fundamental issues, for example, genetically modified foods are confused with gene therapy. It can be difficult for some people to appreciate why one branch of gene technology is seen as a possible threat to the way we live whilst another branch is considered to be advantageous. The sheer scope of scientific knowledge makes it impracticable for future citizens to be taught about all aspects of science, though science has an important place in the curriculum and needs to give people an accurate, if somewhat broad, understanding of scientific issues.

2.4.2 Understanding that scientific advances can cause unexpected and unwelcome problems

Scientific and technological advances involve risk and have, in some cases, caused greater difficulties than the problems the advances were designed to solve. For example, CFCs, once utilised in a great range of aerosols, have been identified as instrumental in the depletion of the ozone layer; adding animal protein to the normally herbivorous diet of cattle is considered to have resulted in the BSE crisis; giving animals food impregnated with antibiotics has contributed to the development of antibiotic resistant pathogenic bacteria. It is difficult for people to see how scientists can be trusted when such problems are a direct result of scientific developments.

2.4.3 People cannot deal with conflicting evidence from scientists

People are often presented with conflicting evidence from the 'experts'. They hear scientists putting forward contrasting views on issues, for example, the effects of alcohol on life expectancy or whether genetically modified crops are safe to plant in the UK. The general population, mainly composed of non-scientists, have to consider whom to trust, whose views to accept, and, possibly, whether they trust any of the claims being made. The uncertainty of answers amongst scientists reinforces the hostile feelings people may have towards scientific advances. As a result, certain scientific advances are perceived with suspicion and misgiving (Osborne 2000).

These three causes of mistrust are unavoidable to some extent, though scientists do have some responsibility themselves for making issues and debates more understandable to the general public. The next section clarifies what could be addressed by educationalists in order that the trust in science and scientists might be cultivated in the future.

2.5 Preparing future citizens

This section considers how future citizens could be better prepared to deal with controversial issues of a scientific nature. It is proposed that they will need to be able to:

- make judgements about scientific issues they do not fully understand;
- understand that scientific developments may involve risk;
- be able to evaluate evidence from different sources.

Decision-making in the future will almost certainly involve people in analysing evidence. No matter where people obtain their information from, be it newspapers, magazines, television or the Internet, an important skill in handling information will be to know how to disentangle opinions and interpretations from fact (Duggan and Gott 2000). To make this distinction people will need some basic comprehension of scientific concepts, for as Wellington and Osborne have pointed out, to be able 'to read science means that one must be at least partially fluent in the language of science' (2001:138). Thus in order for people to make judgements about the validity of different sources of evidence, they will need to understand some scientific concepts.

If science education is going to change in order to prepare future citizens more effectively it is important to analyse how sources of evidence on scientific issues are used and how people cope with often confusing and contradictory opinion in judging when to trust and in evaluation of risk. Clearly, these skills and understanding cannot be addressed in isolation and there is considerable overlap between the issues. However, each matter will be considered in turn to show what steps are needed in order to ensure better educational provision in the future.

2.5.1 Making judgements about issues that are not fully understood

As explained previously, education cannot hope to teach everyone the knowledge required to understand all future scientific and technological change. However, people will have to form opinions about these issues and they will have to draw their information from somewhere. Journalists are a crucial source of information on developments in science but often they simply communicate debates between scientists. Ultimately, if people are to form their own opinions on issues they do not fully understand, they are going to have to make judgements about which 'expert' to believe. People have to accept that they are dependent on the scientists for explanations about new scientific ideas and that just because scientists may put forward conflicting claims this does not mean that trust in scientists is misplaced.

Norris (1995) argues that non-scientists cannot analyse scientific knowledge and, as a consequence, are 'epistemically dependent' on the scientists. Despite this dependence, Norris suggests that non-scientists should create some epistemic distance between themselves and the scientists:

> Having epistemic distance from science implies that some claims are heard but not believed, and that others are heard and believed. Without any epistemic distance, it would not even occur to a person even to ask whether a claim should be believed.
>
> (Norris 1997:253)

If people recognise that developing scientific knowledge may involve approximation and compromise, they may appreciate that it is possible to have a debate about the validity of scientific claims. By appreciating that as new scientific knowledge develops, different and conflicting ideas are involved and ideas may be rejected as new evidence comes to light, people may come to understand that disagreement between scientists is part of the process of advance. In this way, arguments between members of the scientific community will be accepted and different beliefs respected. People can focus their attention on evaluating the strength of the arguments being put forward rather than dismissing science and scientists as being confused because there is not immediate agreement.

2.5.2 Understanding that scientific developments may involve risk

Members of the public should also appreciate that, if they are learning about science-in-the-making, ideas may be tentative and may also bring unexpected and unwelcome consequences. As Ratcliffe (2002) indicates, there may be a social impact resulting from cutting-edge science and this consequence is not often made clear to the public. In some cases, and BSE is a good example, scientists may not recognise that there could be a problem arising from a new scientific approach. So society does need to appreciate that there is often an element of risk with new scientific discoveries and that risk will always be associated with scientific development.

Much of the public's confusion about how scientists can appear to be so wrong may be due to a lack of understanding about how scientific knowledge develops. It is important that people appreciate the ethical dilemmas that are to be faced as scientific and technological knowledge increases. Scientists and politicians have roles to play in educating people about the advantages and disadvantages of some scientific discoveries and the value of risk-benefit analysis. For example, people should be able to weigh up evidence associated with the risks linked to the MMR vaccine. By studying the available scientific evidence and comparing this data with public perception of the risks people may begin to understand how risk is calculated and appreciate that risk can be both exaggerated and underestimated.

In order that people can engage critically with such issues they will need to be able to make a sensible assessment of risk (Millar and Osborne 1998). In this way they may begin to cope better with the unpredictability of some scientific developments. Also, as has already been established, people need to be aware that they may well be presented with conflicting evidence or evidence that challenges long-held beliefs; therefore it is important that they develop the skill of judging where one's trust is best placed.

It follows from the above analysis that an education programme designed to assist future citizens to comprehend scientific debate needs to equip children with the ability to distinguish evidence from opinion and to appreciate that issues are seldom clear cut.

2.5.3 Evaluating evidence from different sources

We need to identify the sources of evidence most people will use when making decisions so that we can plan to improve public understanding of the nature of scientific evidence. Ratcliffe (2002) suggests that much of the evidence explored by people comes from newspapers. In fact, many people glean their knowledge of scientific issues *only* from newspapers (Zimmerman et al. 2000). There is a danger that the views presented by journalists will be accepted without question as many people do not have the knowledge or skills to evaluate these reports. If people merely adopt a view or opinion without considering the evidence themselves, they are not engaging effectively in any debate. As Zimmerman, Bisanz et al. point out, we must all rely on journalists, to some extent, to keep us informed of scientific advances, but there is a need as well for us to be able to read and critically evaluate reports of science in the popular media, to reflect on the evidence reported and not to accept conclusions without question.

2.6 The role ofeducation

It has been argued that for people to play an active part in debate on scientific issues, they need to be able understand that contention is a normal part of the process, recognise that scientific development involves risk, to evaluate sources of information and have an ability to judge whose opinion to value most highly. Unless these issues are addressed in education today, future citizens will be unable to deal rationally with the issues with which they are faced. As Fisher (1998) explains, education needs to provide children with skills appropriate for today and which enable them to cope with a future in an unpredictable world.

The following sections draw from the literature to explore the role that science education plays now and might play in the future. Key criticisms of the science curriculum are identified and recommendations are made for improving the curriculum to better prepare young people for their future.

2.7 The science curriculum today

It is clear that many authors (Driver et al. 1996; Burden 1998; Millar and Osborne 1998; Reiss 2000) contend that the science curriculum does not fully reflect the need for the development of an active and 'scientifically-literate' citizenry, that is, one that has scientific understanding and is able to participate in the democratic decision-making of modern life.

To be able to suggest ways to improve the curriculum, the reasons for the current dissatisfaction with the educational provision need to be considered. In the last decade the science curriculum in England and Wales has been in a state of flux, and there has been a lack of cohesion between educators and policy-makers in constituting the science curriculum (Nicholls 2001). The main dissatisfaction with the curriculum concerns the lack of preparation for pupils to cope with a society that is unpredictable and where the scientific understanding required by future citizens is difficult to anticipate. Listed below are the main criticisms levelled at the curriculum and each point is discussed in the following sections. Examples are provided to show how the curriculum misses opportunities to provide pupils with a science education that is relevant to them as children and as future adults.

The key criticisms are that:

- the curriculum is designed more for future scientists than for the general population;
- science content is still the overwhelming focus of the curriculum;
- science is portrayed as a fixed body of knowledge.

2.7.1 The relevance of the science curriculum

If, as Millar and Osborne (1998) suggest, the current science curriculum has been designed fundamentally as preparatory education for future scientists, then it is becoming increasingly irrelevant to both the needs of the large majority of future citizens and to those of society as a whole. As Reiss (2000) argues, a science curriculum that focuses itself on the needs of a minority of pupils cannot serve the needs of the majority. Millar et al. describe the curriculum, as '... ill-suited to the needs of the majority, lacking any explicit aims and a rationale' (1998:19). It is unsurprising then that pupils find the school version of science dull and uninspiring and fail to pursue science courses post-16 (Millar and Osborne 1998). The Roberts Report (Roberts 2002), commissioned by the four higher education funding bodies, has shown that the number of pupils taking AS-levels in physics and chemistry and the number of students taking these subjects at degree level continue to fall. One way of engaging pupils would be to demonstrate the relevance of what they are learning through including the study of contemporary issues that cannot perhaps be defined in detail in a syllabus or a set of specifications.

2.7.2 The main focus of the curriculum is content

A science curriculum perceived to be focused on content and subject knowledge is coming under more and more criticism (Millar and Osborne 1998; Osborne 2000; Turner 2000a). One reason why the acquisition of scientific knowledge alone is an unsatisfactory educational goal is that the knowledge base of science is expanding rapidly. If the current curriculum is, as Turner (2000a) believes, still similar to the grammar school curriculum of the post-second World War period, then it cannot reflect a changing knowledge base. It is unsurprising that the curriculum may be perceived as lacking relevance. Yet, despite the general increase in scientific knowledge it does not follow that the entire curriculum has to be constantly changing. Much established scientific knowledge has a firm base that is not challenged by new developments and the curriculum needs to reflect this aspect.

However, as Duschl (1990) acknowledges, teachers of science have to recognise that they will be faced with more instances where aspects of the curriculum will have to be modified in the light of new knowledge and new scientific procedures. For example, projects have been set up so that biotechnology practicals, such as bacterial transformation and DNA fingerprinting, can now be carried out in schools. The gap between what is known by the experts and what is known by the teachers will constantly need to be addressed and the challenge of the curriculum is how pedagogy is able to cope with this dynamic aspect of the subject. Indeed, there are many areas of science which are unrepresented in school science curricula, particularly as Hurd (1997) notes, those which focus on human welfare and social and economic progress.

Norris (1997) however, is critical of the notion that just because our knowledge and understanding of science is constantly growing, the curriculum should be based on what he terms 'content-transcendent goals'. A content-transcendent goal, Norris explains, is one that can be achieved through the study of any content. For example, such a goal could be 'to develop a respect for science' or 'to appreciate that science is fallible'. Arguments for teaching content-transcendent goals include that science content can change and therefore we would be teaching out-of-date content and that it is difficult to select what content to teach because of the 'unmanageable immensity' of science. Norris claims that these arguments cannot be justified. He argues that if only the durable aspects of science are taught then we face the problem that we cannot know for certain which of the content will become obsolete during the students' lives. He also points out that people need to have a current understanding in a field otherwise there will be no basis on which to build a new understanding.

Burden, on the other hand, believes that there is much information available which may be true today but not necessarily true tomorrow and therefore the teaching of knowledge or 'facts' has become '... an extremely inefficient and ineffective way of preparing young people to meet the challenges of the future' (Burden 1998: 4). Fisher

(1998) agrees with this view and suggests that it is difficult to assess what factual knowledge will be needed in the future.

Davidson and Worsham (1992) describe these contrasting views on the science curriculum as two 'camps' with which educators may align themselves, the 'content/knowledge' camp and the 'process/thinking improvement' camp. Although much of the content in science is based on well-established facts that have become virtual certainties, during the twentieth century there was a tremendous increase in knowledge. If science education is to reflect these two aspects of science it makes the optimal content for schools' education programmes even more difficult to define. Yet, the National Curriculum is still content-driven and reflects a lack of appreciation for what should be the basis of an education programme for an unknown future (Osborne 2000).

2.7.3 Science is portrayed as a fixed body of knowledge

The National Curriculum, in current use in England, specifies what children must learn in science, but as Millar and Osborne (1998) point out, it presents science as a body of knowledge and as a set of 'facts' to be learned. So science is portrayed within the curriculum as established knowledge which is no longer questionable (Cross and Price 1996; Driver et al. 1996). As long as school science comprises well-established laws and long-accepted theories, it will continue to reinforce the idea that science is absolute, thus people will remain unfamiliar with how scientists use uncertain and contested knowledge to make decisions. It is, therefore, perhaps not surprising that adults associate 'science' with 'certainty' and expect science to provide completely reliable knowledge. Furthermore, as Driver et al. (1996) argue, people need to recognise that scientific knowledge itself may only be a component in a complex process of decision-making which can involve social, economic, ethical and political considerations.

From their experience of the National Curriculum, children are likely to develop the idea that science is based on secure knowledge, with no consideration at school that science provides ‘only provisional truths but nevertheless these truths are often robust’ (Reiss 2000:18). The curriculum does not prepare them for the uncertainties of science in the future and they face the prospect of being ill-equipped to deal with socio-scientific issues as are the adults of today. It follows that children should be made aware of the tentative status of some aspects of scientific knowledge so that they are better able to cope with uncertainty when having to make choices and decisions.

2.8 Developments for the future

The above criticisms of the science curriculum indicate that change is required in order to meet the needs of future citizens. It is important, however, to be clear how the curriculum might be more relevant. The areas for development in the science curriculum appear to fall into three main categories. It is proposed here that pupils need to develop:

- analytical skills to make judgements about the reliability of scientific evidence;
- an ability to make judgements about the validity and strength of conclusions
- an appreciation of how scientific knowledge develops and that some scientific issues are unresolved.

2.8.1 The development of analytical skills

If we accept that some of the scientific issues confronting society in the future will be too complex for non-scientists to understand then science teachers will need to develop pupils’ skills so that they can participate in debate about controversial issues. Although there is currently some teaching about controversial issues raised by contemporary science, pupils are provided with little opportunity to develop the skills necessary to solve problems where they have to search for and evaluate evidence (Watson et al. 2000).

To ensure that students develop skills to be critical of what they read, Zimmerman et al. (2000) suggest that schools should focus on 'identifying and teaching foundational analytic skills with enduring intellectual value.' Carré (1998) suggests that it would be more realistic to relate school science more closely to the thinking that is needed to address the problems the children will encounter as adults. As knowledge becomes more accessible to people through technological advancements, it will be their ability to reason and use the knowledge that will be a key tool of the future.

Examining the way the media report contemporary scientific issues could be used as a teaching focus for developing children`s reasoning and analytical skills. In their analysis, children would need to examine the way the evidence is presented, whether alternative views are reported, and appraise the claims put forward by each author. Such activities would prepare children to analyse future issues and help them develop their own opinions based on careful reasoning and sound judgment.

However, exposure to conflicts in science is not enough; pupils also need to be taught how to develop criteria for evaluating the conflicting views and how to cope with unresolved conflict when resolution is not possible (Norris and Korpan 2000). These points are considered in the next two sections.

2.8.2 Judging validity and strengths of conclusions

The ability to make judgements about the validity and strengths of evidence requires the ability to think and reason scientifically. Although the teaching of these skills is explored more fully in chapter 3, the key issue relevant to this section is how thinking and reasoning skills can be developed to enable children to make reasoned judgments about conclusions.

Activities that present children with cognitive conflict, if accompanied by teacher support, have been shown to enhance thinking skills (Adey and Shayer 2002; Serret 2004). Venville (2002) reports that difficulty should be an accepted part of the classroom and that 'talk that explores and explains the task at hand' is a critical aspect of good thinking. Therefore, children need to be set challenging problems and be helped to think and reason to solve the problems. In addition, if children explore ideas together, they will begin to understand that there can be different views and alternative explanations. Although problems can be presented in a variety of formats, solving problems through practical investigation is more accessible to younger children whose reading abilities may be limited. However, there has been little emphasis within the National Curriculum on the kind of discussion or analysis surrounding issues that permeate everyday life. Furthermore, the assessment procedures that influence pedagogy have been based on tasks that rely heavily on recall of scientific facts (Millar and Osborne 1998).

2.8.3 Scientific knowledge comprises accepted and tentative science

If the curriculum focuses entirely on scientific knowledge that is certain, as opposed to giving more prominence to ideas that are uncertain, then children will not have the opportunity to develop the ability to make reasoned judgements about this distinction. Pupils need to be aware that scientific knowledge consists of accepted science *and* provisional science and that there is a need to be able to distinguish between the two. Millar (2000) points out that many science teachers and textbooks convey the message that science is concerned with 'right answers' and so the provisional aspect of some scientific knowledge tends to be ignored.

One possible way for children to appreciate the tentative nature of scientific ideas is to study how scientists in the past made judgements based on the evidence existing at the time. By examining the evidence that persuaded people to accept scientific ideas in the past, pupils may appreciate how our understanding changes as more evidence accumulates. In seeing how evidence did, or did not, support theories that are now no longer accepted, children can begin to understand why scientists make decisions now that could, perhaps within a few months, be reverted in the light of new evidence. This understanding may then enable children to have a respect for scientists who present conflicting evidence about current issues.

The vast majority of scientific knowledge taught in schools is *not* changing constantly; pupils are, for example, taught about how plants photosynthesise and how metals react with acids and these concepts are not likely to be found erroneous in the future. But it is important that science education also exposes pupils to issues that have not yet been resolved. They could consider, for example, how young female athletes and dancers make decisions about their diet that results in building muscle at the expense of developing osteoporosis in later life. Arguing about such issues that have some relevance to their lives and yet have no immediate answer, will highlight the need for them to be able to assess the quality of evidence and to appreciate the element of risk involved with such decisions.

Conclusion

The National Curriculum, in all its versions, has purported to hold scientific investigative skills in a place of importance and yet, 14 years on from its introduction, we still are faced with a curriculum where the assessment procedures encourage teachers to feel their main role is imparting information. There are, however, some encouraging signs that the Department for Education and Skills (DfES) recognises the need to include the idea of changing scientific knowledge and understanding debate within the curriculum. The Key Stage 3 Strategy indicates that pupils should be taught how to consider how early scientific ideas do not match present-day evidence and how they have changed over time (DfES 2002:13).

Such changes will be important for, as Fisher (1998) points out:

> Many scientific theories, concepts, laws and methods are tentative. Students of science need to know how to work with knowledge, but also be aware of its limits. Scientific explanation might not be the only kind of explanation and it may not be a complete explanation. No matter how certain we are from the evidence of experience there is always the possibility of doubt
> (Fisher 1998:213)

The National Strategy makes explicit the aspects of scientific enquiry that pupils should be introduced in Year 7, and places emphasis on 'evaluating the strength of evidence'. In Year 8 pupils are expected to 'consider whether an enquiry could have been improved to yield stronger evidence' and in Year 9, to 'describe how evidence … supports or does not support a conclusion'. How these developments will impact on the science curriculum for Key Stages 1 and 2 remain to be seen.

Summary

It has been argued that students faced with a future in an unpredictable world will need to be able to reason and think critically and therefore schools should be less focused on imparting information and should place more emphasis on teaching students to learn and think for themselves. Society is undergoing fundamental and rapid change due mainly to scientific and technological advancements. To respond effectively to these changes, society needs individuals who are able and equipped to make informed decisions about ever-changing issues. To do so, people need to have a certain understanding of the science and the ability to evaluate critically the evidence available. Education should prepare young people to deal with controversial knowledge, to recognise bias and to look for alternative interpretations, viewpoints and sources of evidence. The next chapter examines how such skills can be taught in schools most effectively.

Chapter 3 Science Education and the Development of Thinking and Reasoning Skills

3.0 Introduction

In chapter 2 it was established that schools should be less focused on imparting knowledge and should concentrate on imparting general information-handling skills. More specifically, it was suggested that people need to be able to evaluate and assess new information so they can make judgements for themselves to make rational decisions. The evaluation of information requires the ability to reason and think critically and this chapter concentrates on how such skills can be characterised and incorporated into education. Central to the research reported in this thesis is the idea that the way people reason and think can be demonstrated by the way they construct arguments. Some of the existing literature on 'thinking and argument' is reviewed to show how arguing, whether as an individual or as a collaborative activity, reveals the way people reason and think.

The role of education in developing thinking and reasoning is discussed and the case for teaching the skills of argument in schools is examined. The debate about teaching thinking skills in specific programmes or within subjects is explored. It is recognised that although there is support for separate thinking skills courses, it would be more pragmatic to introduce the teaching of thinking skills within subject areas because the curriculum is already overcrowded and the National Curriculum provides little flexibility.

The part the current school curriculum plays in the development of critical thinking, how it is played, and, in particular, through which subjects such thinking should be taught, is then discussed. The potential of science education to develop children's thinking and reasoning skills is studied with particular reference to the idea of conceiving 'science as argument'. Here, the focus is on the way children analyse evidence and its bearing on different scientific theories. The case is advanced for the inclusion of argument in science education and the chapter concludes with a suggestion that these skills need to be addressed early in a child's education.

3.1 The need to teach thinking and reasoning skills

The central premise of this chapter is that people need to learn what it means to 'think critically' in order to reason and form opinions to make decisions in a rational way. To draw conclusions based on rational thought requires the ability to argue and to reason. Reasoning engages people in the analysis of information, an appreciation of the uncertainty of new information and an understanding that views held might change as knowledge develops. They also need to be able to predict possible consequences of actions they might make or decisions they might reach. As many adults of today appear ill-equipped to think critically (Quinn 1997) we need to ensure that our young people, as the adults of the future, do develop the ability to think and reason. Consequently, it is crucial that the teaching of critical thinking is a fundamental part of education in order to enable children to develop skills that prepare them to cope with unknown situations and new knowledge when they reach adulthood.

It was argued in the previous chapter that an education system focused mainly on imparting knowledge to pupils fails to prepare young people for a society where previously held ideas can change in the light of new discoveries. To focus pedagogy on the teaching of facts also fails to prepare them for the world of work because *having* knowledge is already losing its competitive advantage in the business world. Stewart (1997) describes how we have moved from the Industrial Age to the Information Age; the ubiquity of information technology means that information is more accessible and consequently acquiring knowledge is becoming easier. Stewart believes, therefore, that organisations need to focus on how to manage knowledge and to use knowledge effectively. The ability to use knowledge requires people to think effectively. Fisher advocates the teaching of thinking skills and points out:

> that society has changed and that skills appropriate a generation ago may no longer prepare students for the world beyond school.
>
> (Fisher 1998: 8)

Fisher describes society as moving from an industrial-era towards a knowledge-intensive society. Such a shift has created new demands in the skills required of the workforce. Thus, the ability to understand and evaluate information is crucial. In this context, *thinking* is the tool of the future, and a major resource for a nation will be its 'intellectual capital'. Stewart (1997) defines intellectual capital as 'collective brainpower' and he explains how companies are now seeking people experienced in knowledge management.

However, success in the world of work requires an assortment of higher level thinking skills (Hurd 1997) and therefore, one of the aims of education must be the development of critical thinking skills. The idea that thinking should be taught in schools is not new but how it should be incorporated in the curriculum is contentious. Whether the teaching of thinking should be a discrete programme or whether all subject areas need to 'embrace a philosophy that sees thinking as central' (Williams and Burden 1998:189) is an issue that remains unresolved. Some of the main issues are discussed in the following sections.

3.2 Teaching thinking

The lack of agreement as to where thinking should be taught in the curriculum reflects a lack of consensus as to whether:

> thinking supposes a certain basic knowledge and is therefore in a certain sense 'domain-specific' or whether thinking skills and dispositions for thinking apply to all subjects of the curriculum.
>
> (Hamers and Overtoom 1997: 21)

Different approaches are apparent in the programmes for teaching thinking in Europe (Hamers and Overtoom 1997); some programmes have a generic approach to thinking skills while others aim to develop the skills through specific subjects. However, when there are so many different theories on the subject of thinking, perhaps it is not surprising that agreement has not been reached as to one approach's overall effectiveness. The arguments for teaching thinking skills as a separate subject or within other subjects are now discussed.

3.2.1 Thinking skills programmes

There are different views about the pedagogy of thinking with some educators being proponents of thinking being taught as a subject (for example, de Bono, Feuerstein). Teaching programmes have been devised as a consequence of this view (for example, CoRT Programme, Instrumental Enrichment). However, there is also a substantial body of opinions based on various arguments that support the opposite view. Burden (1998), for example, documents the case for and against separate thinking skills programmes but decides that, in his view, teaching pupils to think effectively should be applied to all curriculum areas.

According to Nisbet (1991), the key issue is whether thinking can be taught independently of subject content and whether the skills taught in separate programmes transfer to other domains of thinking. McPeck (1990) firmly supports the view that critical thinking is best taught through familiar disciplines as he believes that critical thinking cannot be applied generally across subject-area domains. A separate thinking skills programme implies that thinking is a generalised skill and that children will be able to apply this style of thinking to any context. However, knowing *how* to think does not necessarily mean children will know when to apply the skills of thinking to a new situation.

Coles and Robinson (1991), who are also critical of teaching thinking skills in a separate programme, suggest that such an approach does not allow children the opportunity to examine their own thinking or to see the links between different areas of knowledge. If we want children to be able to think critically about knowledge they need to develop a disposition to be sceptical about knowledge. Children need an understanding of how they think about new information so that they become accustomed when receiving new information to look for the evidence that supports or refutes the claims being made. The skills the children develop must be transferable skills so that they can think critically about new knowledge that they acquire as adults. Therefore, children need to have a subject to think about and specific subject areas would provide the contexts through which thinking skills could be developed.

Aside from arguments about the effectiveness of separate programmes on thinking skills, there are also logistical issues to be considered. Coles and Robinson consider the benefits of a model in which thinking skills are taught in separate courses in addition to the alternative of being infused into the entire curriculum, but they recognise that:

> in the present British educational climate, finding resources of time, teacher expertise and funding for discrete courses of teaching thinking has its own obvious problems.
>
> (Coles and Robinson 1991: 18)

Although a two-pronged approach may be an effective way of teaching thinking skills, it is most likely that the teaching of thinking will be developed in schools through subject areas; adding another subject to an already overcrowded curriculum is unlikely to happen (Burden 1998).

3.2.2 Teaching thinking through subjects

Within each subject discipline there is knowledge unique to that subject and so the thinking skills required for that subject may also have a unique element. This being the case, it follows that it is important that all subjects develop pupils' thinking skills.

Williams and Burden, having reviewed the teaching of thinking through different disciplines, conclude that:

> there is absolutely no point in contemplating how to enhance cognitive ability separately from all the other aspects of the educational process.
> (Williams and Burden 1998: 196)

However, it is important that we recognise that there are certain skills that are required across subjects. For example, when learning about both science and history pupils need to have a critical approach to the range of evidence available. Mathematical skills, such as interpreting graphical information, are required in many subject areas including science, geography and history. So, when planning *how* and *when* thinking skills are taught in the curriculum via a range of these areas, it is important that there is coordination between *all* subject areas.

There are programmes currently available for use in schools that are designed specifically to enhance children's thinking skills in a co-ordinated way through subject areas (Adey 2000). One very successful project now used in many schools is the Cognitive Acceleration through Science Education (CASE) project. This project, intended to promote children's thinking through subject areas, started with science in 1984 and has now spread into all areas of the curriculum (Adey and Shayer 2002). This project will now be examined in more detail in the next section.

3.3 Cognitive acceleration

The work on cognitive acceleration programmes is associated with the work of Michael Shayer and Philip Adey in the UK (Adey 1997a). Their approach to developing children's thinking skills involves giving children experiences that challenge their ideas, involve them in thinking about their own thinking and encourage them to express ideas as they form (Adey 2000). This approach has been applied to a series of subject based and co-ordinated programmes.

The first in the series was the CASE project, where the approach was to teach science thinking skills as a part of the science curriculum. CASE was introduced in schools in 1984 and involved a two-year intervention programme where pupils in years 7 and 8 carried out a series of activities designed to develop the higher levels of thinking required in science. The findings of the project demonstrated positive short, medium and long-term effects on cognitive development.

In the secondary age range CASE has been followed by Cognitive Acceleration through Mathematics Education (CAME) in 1993, Cognitive Acceleration through Technology Education (CATE) in 1994, and the Wigan ARTS (Arts, Reasoning and Thinking Skills) project in 1999. In primary schools the first project introduced was CAME Primary in 1997, followed by CASE@KS1 in 1998, CASE@KS2 in 2000, and CAME@KS1 in 2001 (Adey and Shayer 2002). Adey explains that all cognitive acceleration interventions are based on three basic hypotheses. These are:

> 1 it is valid to work on the basis of some *general* intellectual function in children which underlies any particular context (subject)-dependent component;
> 2 this general intellectual function develops with age; and
> 3 the development of this general function is influenced both by the environment and by maturation.
>
> (Adey 2002: 3 italics in original)

The question for schools is, what sort of environment can further the development of children's intelligence? In other words, what sort of activities can provide the maximum stimulation to the intellect? This question will be now considered in the context of the CASE intervention and its underlying theory.

3.3.1 Cognitive acceleration through science education (CASE)

The CASE project's main purpose was to provide intellectually stimulating activities in science to maximise pupils' cognitive development. The design of the project drew on the work of Piaget (1896 - 1980) who proposed a model of cognitive development that implies a hierarchy of stages in the way children's cognition develops.

The CASE project's main aim was to promote ways of teaching that enabled children to move up through these stages. Piaget's empirical study led him to identify four major stages of cognitive development.

1 Sensor-motor Thought (age 0 - 2 years)

2 Pre-operational Thought (2 - 7 years)

3 Concrete Operational Thought (7 - 12)

4 Formal Operational Thought (12 years plus)

(Greig and Taylor 1999: 29)

Accordingly, in CASE tasks were put together that were challenging and designed to develop cognitive growth by providing cognitive conflict, that is, events or phenomena that the children would find puzzling. Cognitive conflict challenges a child's thinking because it may be discordant with previous experience. In this way the CASE activities help to accelerate children's cognitive development, for example, from concrete to formal operational thinking.

In designing an intervention intended to accelerate pupils through the stages of cognitive development, the CASE project design also drew on the work of Lev Vygotsky (1896 - 1934), a Russian psychologist and a contemporary of Piaget. Vygotsky believed that language is a communicative tool by which we share experiences and make sense of these experiences together. As a result of sharing ideas, new knowledge is developed as a collaborative activity (Mercer 2000). Vygotsky argued that conversations between adults and children are crucial for cognitive development and that children could achieve more with intellectual guidance and support from an adult than they could alone. Essentially, children can perform tasks of a higher level working with another more experienced person than they can working alone.

The zone between what a child can achieve alone and what can be achieved with support Vygotsky termed the 'zone of proximal development' (ZPD) i.e. the ZPD is the difference between the actual performance and the potential performance of a child (Greig and Taylor 1999). The task of the teacher is to help learners move through this zone to the next level of understanding (Williams and Burden 1998). The relevance of the ZPD to the design of the CASE teaching approach is that it suggests that children learn when they are allowed to talk about and discuss their ideas with adults. The 'Vygotskian' aspect of CASE is explained in detail by Gamble and Shayer (2002) but essentially tasks are set for small group discussions which, then lead to a whole-class discussion *managed by the teacher.*

Through discussion, within groups and through whole-class discussion with the teacher (Wilson 2002) children were required to reflect on their own problem-solving process skills and develop metacognitive skills. As Adey (2000) points out, this introduced the Vygotskian element of metacognitive reflection which, in his view, was one of the essential features of a successful intervention.

CASE produced a set of activities called 'Thinking Science' (Adey et al. 2001) to facilitate this type of learning experience in science lessons for years 7 and 8 (11 - 13 year old pupils). There is evidence to show that pupils involved in this two-year programme:

> not only show significant gains in cognitive development over the two year period, but subsequently show increased academic performance in national public examinations in English and maths, as well as in science, up to three years after the intervention programme.
>
> (Adey 1997: 175)

Adey is clear that the time spent in developing the children's intellectual abilities in the first two years of secondary schooling 'pays off …in subsequent years'. Both National Curriculum tests and GCSE results in English, mathematics and science subjects provide evidence for long-term benefits of the CASE intervention and for the transfer of thinking skills (Adey 1997b).

Following on the success of CASE in the secondary age range, a cognitive intervention programme was developed for children in primary school. This programme is the subject of the next section.

3.3.2 Cognitive acceleration in primary school science

An important development in the CASE programme is the current move into primary education and the study of cognitive acceleration in pupils in Year 1 (pupils aged five to six years old) and more recently in Year 3 (pupils aged seven to eight years old). These projects, known respectively as CASE@KS1 and CASE@KS2, represent one of the few current research programmes on developing thinking skills with younger children.

In these programmes, activities are being produced to develop children's thinking skills in the context of science where children are required to solve problems in small groups. Early reports on the project at Key Stage 2 indicate that providing children with a forum where they are expected to negotiate has made a positive impact on the children's social skills, both in the classroom and in the playground (Wilson 2002).

3.4 Thinking and argument

If, as the CASE team claim, certain teaching activities can stimulate intellectual development, then the case that science education can play an important role in developing children's thinking and reasoning skills is strengthened. The contention here is that these skills can be promoted through activities that require pupils to discuss, challenge, oppose and negotiate, in short to argue. It is, of course, logical that argument is an important feature of thinking and reasoning because, in justifying a case, evidence must be examined and counter arguments must be considered. Reasoning also requires people to see other points of view and to be open to a change of mind. In order to incorporate thinking skills into an educational programme we must be able to identify the way a person thinks. Once we know how these skills are demonstrated then we can plan ways to enhance the use of these skills and assess their development. It will then be possible to evaluate the success of programmes designed to develop such skills.

Billig (1996) suggests that the structure of our thoughts can be demonstrated by the way we structure an argument. Likewise, Kuhn (1993) claims it is in argument that people demonstrate the way they think and reason. To accept these views of thinking as argument suggests that parallels must exist between good thinking and good argument. To argue well, people need to be able to discriminate between truth and falsehood, to reason accurately and to be able to weigh up evidence and since these skills are also related to critical thinking, both Billig and Kuhn's views would appear to be substantiated.

To judge the quality of the thinking used in constructing an argument there needs to be a means by which the quality of the argument can be assessed. The following section outlines the template for describing arguments that has been adopted in this research.

3.4.1 The features of an argument

Stephen Toulmin's seminal work, *The Uses of Argument* (Toulmin 1958), has been used by science educators to help identify the structure of arguments (Driver et al. 2000; Simon et al. 2003). Toulmin presents a model of the structure of argument drawn from everyday situations. He has identified a pattern that can be used to analyse argument structures to show the reasoning that has taken place to support and establish a claim.

In its simplest form, Toulmin considers that an argument consists of a 'claim' with a reference to 'data', which are the facts that have led to the claim being made. The claim is an assertion that has to be supported by these facts if it to be considered an argument. People have to think and reason in order to justify their claims and consequently support their argument. The explanation of how the facts or data support an argument are referred to by Toulmin as the 'warrant' and 'backing'. Warrants provide the reasoning to justify how the data supports a claim; the backing provides the justification for the warrant. The 'good' argument is one that can be justified, can stand up to opposition and where the evidence is strong and the warrants legitimate.

If education is to facilitate the development of people's argumentation skills, situations will need to be engineered where children can utilise these skills and see how contentions only become arguments when supplied by reasoned warrants and legitimate backing. The term 'argument' can include:

> everything from the tentative and mutual exploration of an idea in a harmonious fashion - by an individual, pair or group of people, in speech or writing - to formal debate or acrimonious row or fully-fledged written statement of a position.
>
> (Andrews 1995: 4)

However, it is important to establish whether an individual exploring and justifying ideas uses the same skills of argument as two or more persons discussing and debating ideas together.

As an individual activity, argumentation that attempts to persuade others to come to a particular point of view or belief is known as a rhetorical argument; as a social activity, argumentation that involves negotiation and discussion is known as dialogic argument. Whether these two types of argument require the same or a different set of skills is now explored.

3.4.2 Rhetorical and dialogic argument

On first consideration, it may be thought that it is more straightforward to develop the argumentation process when more than one person is engaged in an argument since they are likely to voice different views. However, even in a rhetorical argument, the individual has to anticipate opposition and present arguments against different points of view. When individuals develop ideas or beliefs, they do so as a result of weighing the evidence presented by different theories (Kuhn 1993) which internalises the debate within an individual as he or she comes to a decision. However, when the debate concerns just one person such argument is most likely to be demonstrated through thinking and writing (Driver et al. 2000). Nevertheless, to reach a resolution in any type of argument involves the refutation of evidence about alternative assertions, and the evaluation of the merits of different points of view. Therefore, both types of argument require a plurality of views and opposition to ideas.

Kuhn suggests that although rhetorical argument may, on the surface, appear less 'complex cognitively', it does in fact require the same skills. Billig (1987) proposes that the thinking a person does as an individual involves an internal silent argument when different views or solutions are evaluated before a course of action is decided upon. So, differences of opinion arise, both for the individual and between the individuals within a group. These disputes will lead to corrections, modifications, retractions and replacements and through reasoning a final understanding should be reached (Kummheuer 1995). So the conclusion must be that the same processes of thinking underpin argument in a group or within an individual.

One of the purposes of argument, both rhetorical and dialogic, is to refine and clarify ideas in order to come to some form of decision. The situations that challenge people to use their skills of argumentation involve events that are difficult to explain or where there is an element of conflict, such as when the evidence is incomplete or contradictory. Reasoning, evaluating and justifying are the skills employed in resolving arguments. However, as discussed in chapter 2, many people do not develop these skills and so clearly they need to be taught. It is important for schools to be aware that argumentation can be developed through both individual and group activities as each situation will involve the exercise of similar skills. The teaching of argumentation in school is the focus of the next section.

3.5 Teaching argumentation in school

Anxiety about the inability of future citizens to think critically is reflected in the Government's proposals for the teaching of citizenship and democracy outlined in the Crick Report (Advisory Group on Citizenship 1998). The Crick Report states that one of the aims of citizenship education is to bring about:

> a change in the political culture of this country both nationally and locally: for people to think of themselves as active citizens, willing, able and equipped with the *critical capacities to weigh evidence before speaking and acting.*
>
> (Advisory Group on Citizenship 1998: 7; italics not in original)

The report identifies the skills and aptitudes that are part of the essential elements of the Education for Citizenship Programme that must be reached by the end of compulsory schooling. Included within the list of skills and aptitudes suggested in the report are the following:

- the ability to make a reasoned argument both verbally and in writing
- the ability to co-operate and work effectively with others
- the ability to develop a problem-solving approach

(Advisory Group on Citizenship 1998: 44)

If, as is suggested in chapter 2, children do not acquire these skills easily then one of the main aims of the education system should be to create opportunities for the development of these skills (Williams and Burden 1998). The development of pupils' skills of argumentation in the curriculum is consistent with the educational aim of developing their abilities to reason about problems and issues in different contexts (Jimenez-Aleixandre et al. 2000; Zeidler et al. 2003). In addition, Nussbaum (1998) believes that it is important to 'learn how to argue' as working in a group requires the members of the group to reason collaboratively. Schools are ideally placed to provide opportunities for argumentative dialogue as pupils can be engaged in reasoning both by themselves and within a group. Kuhn points out:

> In the informal social interaction that is a major part of school experience, ideas are tested and inevitably challenged; thus social experience serves as the natural challenge to individual thought.
>
> (Kuhn 1992: 175)

Kuhn does note that although schools provide these opportunities, they do not do so optimally and she suggests that formal educational experiences offer limited effectiveness in leading students to think explicitly about their own thoughts. Therefore, schools need to develop activities that are more relevant to the classroom.

Cohen (1995) suggests a range of metaphors for framing and understanding the concept of argumentation that is relevant to the classroom. He relates argument to the altering or construction of new meaning ('Argument ... is growth or adaptation'), as an exchange of ideas rather than the imposition of one side's ideas on the other ('Argument ... is metamorphosis') and as constructive co-operation ('Argument ... is brainstorming'). In spite of these ideas for the promotion of argument in school, the demands on teachers may mean that children are rarely given the opportunity to argue unless it is a requirement of the subject. Even though, schools could provide the occasion for children to argue; few opportunities are realised in the classroom. For example, although argument is an important feature of science education as it provides opportunities 'to foster children's ability to think scientifically and their ability to reason from evidence to conclusions' (Wellington and Osborne 2001: 73), it is an activity that is seldom used in the classroom (Newton et al. 1999). However, the role of argumentation in science is now a developing field of study (Watson et al. 2004) and some of the background to these developments is now considered.

3.6 Thinking and argument in science

If teachers can be convinced that giving children opportunities to argue in science will enhance their scientific thinking and reasoning skills then perhaps we shall see more argumentation activities introduced in the classroom. The case needs to be made for the concept of 'science as argument' (Kuhn 1993); Kuhn's view is that thinking scientifically involves constructing an argument because in arguing we have to reason, to think critically and weigh up evidence in coming to a conclusion. Kuhn suggests that characterising scientific thinking in this way can be applied equally to scientists, lay adults and children, although she is unconvinced that such skills are developed in young children.

This concept of 'science as argument' can be applied in two different ways. First, argument can be used in clarifying theories, as in Cohen's 'chains of reasoning' (Cohen 1995). Reasoning to clarify ideas can be an individual activity or it can involve a group of people reasoning together in collective thinking (Mercer 2000). Second, argument can be used in the communication of the new theory to a wider and maybe sceptical audience. How these concepts of argument are relevant to the science classroom are now considered.

3.6.1 Understanding the development of scientific theories and the use of evidence

If young people can appreciate how they themselves might change their minds about certain scientific ideas, then perhaps they may develop a better understanding of the nature of science and how scientists work. When scientists explore scientific ideas the evidence to support contrasting claims is evaluated and leads to one theory being accepted over another. Scientific theories develop as more evidence became available, for example the shift from understanding the solar system as Geocentric to the Heliocentric model. Children need to know that although science includes a body of knowledge that is secure, there are still some ideas where there is dispute and controversy (Driver et al. 2000). They need to understand that theories are subject to change in the light of new evidence and must therefore be regarded as tentative (Harlen 1993). Moreover there is the possibility of children being taught different theories in their secondary school than they were taught in their primary school as new ideas replace older ideas (Duschl 1990). As Osborne says:

> Science-in-the-making is also characterised by a number of uncertainties: empirical uncertainty due to lack of evidence; pragmatic uncertainty due to a lack of resources to investigate the problem; and theoretical uncertainty due to a lack of a clear theory of what is causing the events of interest.
> (Osborne 2000: 233)

If children are made more aware of their own internal arguments as they struggle with some new scientific concepts then perhaps the scepticism with which disagreements amongst scientists is greeted may be avoided in the future. A practical way for children to become aware of their own understanding is to have to articulate and evaluate their ideas through explaining them to one another, and supporting their own reasoning during the discussion that takes place.

Children also need to develop an understanding of the role of evidence in science. They can do this by engaging in argumentation activities. In argumentation, to justify a claim, facts are presented to determine the validity of the claim and these facts are termed 'evidence'. When making decisions about what action to take people have to be able to evaluate claims and to comprehend the different interpretations scientists might make of the evidence available. In the classroom, if children are expected to make a case for a particular viewpoint and defend their ideas against opposing ideas, then it is clear that argumentation in science education can enhance the skills of evaluating evidence in a way that is practical for them as children and relevant for them as adults of the future. As has been explained earlier, the teaching of argumentation is beginning to be taught in schools and the following section presents a brief overview of some of these projects.

3.6.2 Argument projects in schools

There is a growing interest in argumentation in the educational literature (Nussbaum 1998). Much of this work is not located in science education (Pontecorvo and Giradet 1993; Andrews 1995; Anderson et al. 1997) but argumentation in the science classroom has become the focus of some researchers. For example, in the United States of America researchers Eichinger et al. (1991) have studied how sixth grade students (aged 11 - 12 years old) worked on problem-solving activities in science. In this study the way the children resolved a problem was termed the 'solution path' and this path was analysed for the construction of arguments based on theory and evidence. Also in the USA, as part of a wider study, Bell and Linn (2000) examined how students' views about the nature of science aligned with the quality of arguments they constructed when developing ideas on how far light travels. Bell and Linn's study showed how children's understanding of the dynamic nature of science could be enhanced through argumentation.

Argument projects are also being developed in Europe, for example, research has taken place in Spanish high schools with ninth grade students (aged 14 - 15 years old) to identify their capacity to develop and assess arguments in science lessons (Jimenez-Aleixandre et al. 2000). One of the findings of Jimenez-Aleixandre et al's research showed that students used few warrants to justify their claims when engaged in argumentation discourse and consequently recommendations were made to teach argumentation in schools.

One pedagogical strategy, developed in the UK by Keogh and Naylor (1999), is the use of concept cartoons that present learners with an argument about scientific concepts in visual form. The cartoons present different ideas about an aspect of science and can be used 'to generate discussion ... and to challenge the learners' understanding' (1999: 441). Keogh and Naylor report that one of the strengths of the cartoons is that they legitimise argument and invite the learners to engage with and extend the argument themselves. As already shown engaging children in arguing about scientific phenomena requires them to think more deeply about their own ideas, particularly when faced with opposition to their viewpoint.

Research has also been conducted that focuses on improving the students' skills to reason from evidence to reach conclusions and developing strategies that facilitate student argumentation (Simon et al. 2003). This project, 'Enhancing the Quality of Argument in School Science', investigated the pedagogical strategies that are successful in promoting students' (aged 12 - 14 years old) argument skills. One of Simon et al.'s conclusions was that in order for teachers to be encouraged to implement argumentation in school science then a programme of systemic teacher development needed to be developed. One of the outcomes of this project is the production of an In-Service Training Pack for teachers that includes resources for use in science lessons (Osborne et al. 2004).

These innovative projects suggest that the skills of argumentation could be addressed within current science teaching if the National Curriculum Attainment Target Sc1 was taught successfully. However, this attainment target has been the most neglected (Wood-Robinson 2002) and children have not been developing the skills of scientific enquiry, especially in the use of evidence. Wood-Robinson suggests that the skills of scientific enquiry have been developed in the primary school only to be put aside in the secondary school as teachers focus on the factual content of the curriculum. In preparation for secondary school and subsequently adult life, it is the premise of this thesis that it is important to identify the skills in argumentation, and in particular, the skills in using evidence, which primary school children can be expected to develop. Until we know the abilities children have in these skills we cannot plan for progression in the development of these skills. We also need to know the range children demonstrate in these skills in order to establish the different stages in skill development. The science National Curriculum identifies the skills children should be taught and these are examined in the following section.

3.7 The National Curriculum orders about the use of evidence in science

Using evidence is a key feature of both forming ideas and justifying claims. Children need to be taught how evidence affects the way they think about scientific concepts and how new evidence may result in a change of mind. In the National Curriculum (DfEE 1999b) Attainment Target 1 (AT1) 'Scientific Enquiry' identifies the knowledge, skills and understanding that pupils are expected to have and includes details of how children are expected to use evidence at levels 4 - 8. Below are extracts taken from the AT1 level descriptors that relate to how pupils should use evidence. There are no direct references in levels 1, 2 and 3.

Level 4:
Pupils recognise that scientific ideas are related to evidence.
Level 5:
Pupils describe how experimental evidence and creative thinking have been combined to provide a scientific explanation.
They draw conclusions that are consistent with the evidence and begin to relate these to scientific knowledge and understanding.

> **Level 6:**
> Pupils describe evidence for some accepted scientific ideas and explain how the interpretation of evidence by scientists leads to the development and acceptance of new ideas.
> They draw conclusions that are consistent with the evidence and use scientific knowledge and understanding to explain them.
> **Level 7:**
> Pupils describe some predictions based on scientific theories and give examples of the evidence collected to test these predictions.
> They draw conclusions that are consistent with the evidence and explain these using scientific knowledge and understanding.
> **Level 8:**
> Pupils give examples of scientific explanations or models that have to be changed in the light of additional scientific evidence.
> They use scientific knowledge and understanding to draw conclusions from their evidence.
>
> (DfEE 1999b: 74 –75)

If we have a better understanding of how pupils in primary schools relate ideas to evidence in science it would enable teachers to plan for progression in this subject more effectively. The current specifications state that at Key Stage 1, children should be taught that 'it is important to collect evidence by making observations and measurements when trying to answer a question' (DfEE 1999b: 16) but the requirement that children should use evidence when drawing conclusions is not made explicit until level 5. Yet level 4 is the target attainment for the majority of pupils at the end of primary school education. We need to know if these expectations underestimate children's skills in these areas and whether we are missing opportunities to develop children's skills in the primary school.

Wood (1998) suggests that in order for children to be empowered and participate in making choices they need to practice making decisions through the curriculum. She argues that children need to know they have a voice and will be listened to and taken seriously. Therefore, the way children will come to appreciate the importance of evidence is through being expected to use it to justify their own conclusions, even in a simple fashion. The implication is that science teachers need to create activities where children can explore different viewpoints. In this way, children can begin to understand how evidence can persuade someone to change a particular viewpoint. Current practices in schools, however, suggest that the teaching of decision-making skills in science is neglected as will now be explained.

3.8 Teaching thinking and reasoning through the science curriculum

As has been discussed, the scientific enquiry component of the National Curriculum has the potential to engage children in thinking about evidence and make reasoned judgments based on this evidence. So the implementation of the National Curriculum in the UK in 1989, should have seen changes in the way science was taught. However, as discussed in chapter 2, science continued to reflect a positivist view (Driver et al. 2000) where there is a body of known facts that is incontestable. Driver et al. are critical of the science portrayed in schools as a subject where there are clear right answers and which arise from data lead in an uncontroversial way. Mannion et al. (2003) suggest that having been 'brought up on a diet of factual testing' it is not surprising that young people think of science as merely a body of knowledge. They also criticise the practical work carried out in schools because they believe many teachers have honed down their repertoire of practicals to those that work and give reliable and predictable results. Yet there are many areas in the science curriculum where children's thinking and reasoning skills could be developed more systematically, for example, when children are involved in investigative work, when they engage in decision-making exercises as a group and when they learn about controversial issues in science. The following sections expand these ideas further.

3.8.1 Investigative work in science

When carrying out investigations children not only develop manual skills, for example using scientific instruments to take measurements, but also thinking skills as they consider how to make their measurements valid, the reliability of their data and how they should analyse their data. The conclusions drawn from their investigations should enable them to make reasoned judgments to develop explanations about their data. Yet there is little evidence that scientific investigations in schools have resulted in the development of such thinking skills (Watson et al. 2000). The National Curriculum has promoted the introduction of more investigative work but this has, as Driver et al (2000) suggest, failed to represent the speculative nature of science. The way investigations have been carried out in the classroom reinforces an image of a singular scientific method, implying that scientific knowledge has been discovered solely as a result of following a set procedure (Driver et al. 2000). This view has been substantiated by Watson et al. (1999) who concluded from their research that the National Curriculum has led to a restricted set of investigations being carried out by pupils at Key Stages 2 and 3. The practical work is restricted both in content and in style, the 'fair test' type of investigations dominating the children's experiences. This narrow experience, they suggest, will be misleading to pupils if they develop the idea that every science investigation has the same structure (Goldsworthy et al. 1998).

Kuhn calls for a move away from the positivist conception of science to one where '... even the so-called "facts" of science become argumentative constructions that must be entered into the arena of public debate' (Kuhn 1993: 321), and where scientific method is not detached from controversy or from argument. Ruffman et al. (1993) also recognise the importance of skills which enable children to evaluate claims or theories in relation to the evidence and they believe that a full understanding of science:

> requires that children recognise that the hypotheses they encounter in texts are formed on the basis of the available evidence, and which are plausible though not necessarily correct ways of explaining the data.
> (Ruffman et al. 1993:1617)

This process of evaluation is equally necessary for those hypotheses the children may develop themselves and would require the skills that Kuhn has identified as argument. For example, children have to reason and argue their case when defending their own ideas and when challenging another's ideas. Schools are ideally placed to promote such collaborative work, whereby children discuss issues together, and as a result could support the development of higher-level thinking and reasoning processes (Mason 1996). How collaborative learning can facilitate learning and the development of knowledge is now considered.

3.8.2 Collaborative work in science

Mercer (1995) reminds us how we learn knowledge and skills through talking and working with other people who may not be our teachers. He suggests that our own understanding of the issues can be improved through having to explain something to another person who does not understand. He also says that:

> an excellent method for evaluating and revising your understanding is arguing, in a reasonable manner, with someone whom you can treat as a social and intellectual equal.
>
> (Mercer 1995: 89)

Working together means we argue about different points of view, we resolve differences and we create a shared understanding (Mercer 2000). To create a shared understanding in the scientific community, scientists have to be able to validate their discoveries and expose evidence that supports their theories. Scientists also have to present a convincing argument to the non-scientific community in order for their ideas to become accepted. Thus, the process of developing knowledge and teaching others about new knowledge involves collaborative learning. For Kuhn (1993) the advancement of scientific thought by scientists can be linked to the way children develop their scientific thinking. She conceives 'science as argument' as science being a social activity that advances through discussion between people. Therefore, if we are to encourage children to develop their scientific thinking we need to teach them how to argue *about* their ideas in order to clarify what they think and then how to argue *for* their ideas when they try to convince others of their merits. How this approach can be used in schools is now considered.

3.8.3 Children learning collaboratively in science

In order to encourage children to argue in a constructive manner they need to understand *how* evidence is used to support theories; they need to be able to evaluate evidence in terms of its adequacy, its relevance and its source. Just as support for scientific theories can draw on a range of evidence, in the form of numerical data, recordings of observations or other established scientific facts, so children need to explore different ways to justify their ideas and conclusions. In schools, children are expected to carry out investigations for which they make observations and take measurements. Using these recordings pupils should be taught how to evaluate the strength of evidence, how to describe how their conclusions are consistent with the evidence obtained and how to identify the limitations of their data (DfES 2002). In this way, children should develop an understanding how they can argue and defend the conclusions they have drawn.

It has been proposed previously that science as argument can be conceived in two ways; first as a way of clarifying theory or coming to a decision and second, as a way of persuading others to adopt an idea. However, in practice, this distinction is not always easy to make in the context of science in the classroom, as the two processes can become intertwined. Children may clarify their ideas by explaining them to another person, for example, an individual child might communicate a partially formed theory to the teacher. The purpose of such a communication would not normally be to persuade the teacher but for the children to explain their ideas to see if they make sense.

Therefore, we must ensure that science lessons give children the opportunity to explain their ideas to each other and to the teacher for both processes of argument to be involved.

It has already been noted that science education offers many possibilities for children to work collaboratively, and it is more likely that children explore phenomena in a group rather than as an individual. Stockton (1992) suggests that the science classroom is the natural place for the teaching of thinking skills in a co-operative learning setting. When children are given the opportunities to articulate and communicate their ideas they demonstrate their thinking skills by their ability to give valid reasons for their choices and through the evidence they select to support their claims.

With properly designed activities and with appropriate resources, such co-operative learning can facilitate the development of children's reasoning skills as they seek to justify an idea and convince others of its merits. In this style of discussion the children may argue from different positions and in presenting their reasons for a particular standpoint they will be challenged in their own thoughts and also challenge evidence that opposes their view.

Chinn and Anderson (1998) found this type of 'interactive argument' represented a collective search for reasons and that sometimes leads to a change of theory. The analysis of evidence and its bearing on different theories is part of the development the individual's thinking skills and Kuhn claims this is important part of '... what goes on in the private thought of the individual scientist'(Kuhn1993: 322).

Science lessons can also involve pupils working in groups on activities where they discuss ideas to investigate. For example, Richmond and Striley (1996) carried out research with tenth grade students (13 - 14 years old) where the science course followed offered the students opportunities to investigate real-life problems using principles and concepts from a variety of scientific disciplines. They report that:

> One of the most significant changes we observed ... was in the students' ability to formulate appropriate scientific arguments. They became more adept at identifying the relevant problem, collecting useful information, stating a testable hypothesis, collecting and summarizing data, and discussing the meaning of data.
>
> (Richmond and Striley 1996: 847)

Richmond and Striley also found that the discourse during laboratory-based activities revealed how social dynamics helped shape the development of an individual's conceptual understanding of scientific problems. They concluded that the development of equal participation in classrooms should be a critical goal of science educators. Science investigations involve pupils in making reasoned arguments and to develop a successful problem-solving approach pupils have to co-operate and work effectively with others.

Other opportunities in science where children could work collaboratively to make decisions is in the discussion of controversial issues as will now be explained.

3.8.4 Teaching controversial issues

A controversial issue is an issue about which there may be conflicting views on the subject and evidence alone cannot provide the answer to the problems. As explained in chapter 2, many controversial issues concern socio-scientific issues, frequently concerning issues at the frontiers of scientific knowledge (Ratcliffe and Grace 2003). Discussing controversial issues engages pupils in the consideration of the available evidence to decide whether it supports a particular conclusion or not.

There are several examples of issues that present pupils with this kind of decision-making, one example being the issue of keeping animals in zoos. Children can appreciate that there are many issues to consider when deciding whether we should keep wild animals in zoos. We know that for some zoos their key purpose is now the preservation of animals threatened with extinction. Nevertheless, many people consider that keeping animals in captivity is unacceptable. Children can understand that keeping animals in zoos may halt the extinction of some species but the consequences of taking such action means that the decision is not just about what can be done but what *should* be done.

This feature, a choice on what *should* be done or what *can* be done, can be used to distinguish the socio-scientific context from the scientific (Fullick and Ratcliffe 1996). The decision in a socio-scientific context may have conflicting objectives, which is not always a characteristic of scientific decisions. Although scientific evidence can inform socio-scientific decisions, the decisions cannot be based on the evidence alone.

Thoughtful decision-making may lead to an action or to a forming of opinion (Ratcliffe 1996) and is equally relevant in both primary and secondary classrooms. To promote thoughtful decision-making requires a method of teaching that allows pupils to explore ideas by seeking alternatives and testing evidence that both supports and refutes their initial concepts. Studying socio-scientific situations will expose contradictory positions as different claims are made. Encouraging pupils to explore and argue about alternative ideas in this way should support them in developing an understanding of the role of evidence in assessing contrasting viewpoints. It may also reveal errors in the pupils' reasoning as they examine their own or others' fallacious arguments (Zeidler et al. 2003). In examining a range of viewpoints pupils may develop a better understanding of why disagreements may occur among scientists and consequently become more accepting of the tentative nature of some contemporary scientific issues. Pupils may also have a better understanding of the concepts of risk associated with scientific claims that are, as yet, unsubstantiated.

Conclusion

Based on the review of the literature and my own observations of science teaching in the 1990s as a tutor of student teachers, the majority of science lessons support the positivist view of science. Even the investigations selected by the teacher (particularly in the primary school), or those pupils are guided to select, have not been chosen to develop the pupils' *understanding* of science. Rather they are chosen because they allow certain investigative procedures to be carried out. Pupils are rarely allowed to pursue an investigation that 'will not work' for fear of confusing them. Turner (2000) questions why some practical work is carried out since it is so often inconclusive but if pupils only carry out practicals that do work, teachers will inadvertently teach pupils that science always works (Mannion et al. 2003). Therefore, pupils may find it difficult to appreciate that scientific problems do not always have an easy solution.

Turner considers that time constraints in science lessons lead teachers to foreclose a discussion to get to the 'right answer'. Discussions rarely allow pupils to consider *how* they come to a conclusion, they may be able to identify what evidence has led them to make their conclusion but without any understanding of alternative interpretations. Pupils are not often encouraged to pursue other sources of evidence or consider what evidence would disprove the conclusion made. All these practices conspire to maintain the situation whereby pupils have a limited view of the scientific method and an expectation that science has the 'right answers'. It is important to explore how pupils are expected to use evidence in the context of science education so that we might develop some understanding of how this situation has come about.

Summary

In this chapter, the case has been advanced that thinking skills and reasoning are critical for coping with a world of uncertainty and rapid scientific and technological advancements. Thinking skills can be demonstrated by the way people engage in argument and developing argumentation skills will develop thinking and reasoning skills. Some of the developments in the teaching of thinking currently taking place in schools have been reviewed; the review included programmes with a general aims approach and those with a subject specific approach. It has been suggested that science has a particular role to play in developing the skills of thinking through argumentation as pupils are expected to argue their case based on evidence and draw conclusions from data collected. One reason that the skill of using evidence has been neglected in secondary science education is that there is a focus on content in the science curriculum. As concerns are now being raised about the emphasis on the acquisition of facts in science in the primary schools (Roden 2000), the way which the approach to the teaching of primary science has changed, and the effect this has on the development of children's thinking is of concern and thus is the topic of the next chapter.

Chapter 4 Primary Science: Its role in the development of thinking and reasoning

4.0 Introduction

Chapter 3 located the importance for the development of thinking and reasoning skills through science education and made a case for developing such skills through argumentation. In this chapter it is suggested that the skills of argumentation should be developed early in a child's education and that the teaching of these skills can usefully begin in primary school. It is argued that the present science curriculum underestimates children's abilities in argumentation and consequently misses opportunities to develop these skills particularly in the Scientific Enquiry (Sc1) Programme of Study.

A review of the literature reveals disagreement about children's capabilities in the skills of argumentation. These contrasting viewpoints are discussed and the conclusion is drawn that young children are more capable than Kuhn and her colleagues would suggest and that consequently the development of these skills could and should start in the primary school. Why teachers are failing to develop these skills in young children, especially in science where there are so many opportunities for such skill development is then explored. To explore this issue further, the growth and development of primary science in the UK since the 1960s are examined. The approaches taken in the key projects are discussed to show the differing emphases placed on the teaching of skills in the science curriculum. The programmes of study in the successive versions of the National Curriculum are examined to illustrate that the expectations of primary aged children's skills are still unclear, particularly with reference to hypothesising skills. In addition, when the science curriculum (DfEE 1999b) is compared to other subjects in the primary curriculum, and in particular the citizenship curriculum (DfEE and QCA 1999), it is shown that the curricula have different expectations of young children's capabilities, particularly with regard to their skills in argumentation. It is concluded that science education could and should take a much greater role in developing children's argumentation skills especially in the way they use evidence to support their arguments. However, to enable teachers to develop this role effectively, we need to have a better understanding of how children use evidence to make claims and reach decisions in scientific activities. This is the subject of the research undertaken in this study and is set out in later chapters.

4.1 Studies about children's scientific thinking and reasoning skills

It was established in the last chapter that one way to enhance children's thinking and reasoning skills is through developing their skills in argumentation. This view is comparatively new and research carried out so far in this field has been principally with older children in secondary schools (Geddis 1991; Jimenez-Aleixandre et al. 2000; Osborne et al. 2001; Simon et al. 2003). However, there is a body of relevant research that concerns the development of young children's scientific thinking skills. The research comes from a range of studies (Kuhn et al. 1988; Sodian et al. 1991; Samarapungavan 1992; Koslowski 1996; Leach 1999). Although the studies appear to have a consensus on what characterises good scientific thinking, they reach different conclusions about the ability of young children to coordinate theory and evidence. The next section presents some of the views put forward in the literature concerning the development of argumentation skills in young children.

4.1.1 An overview of the work of Deanna Kuhn et al.

Kuhn, Amsel and O'Loughlin (1988), in their seminal work into the development of scientific thinking skills, established that an important way for scientific thinking skills to be demonstrated is through the way theory and evidence are co-ordinated. They argue that the skill of coordinating theory and evidence is one of the most 'central, essential, and general skills that define scientific thinking'; the coordination of theory and evidence enables a person to interpret new evidence using existing theories. When theories are considered a person must be able to judge how evidence supports or refutes the different theories proposed. New evidence may also be used to evaluate and revise existing theories. Thinking in this way is cognitively demanding and requires the kind of skills, Kuhn et al. suggested, that we would expect scientists to have. It is necessary to be able to distinguish theory and evidence in order to evaluate evidence and assess its meaning for the given theory. People who are unable to distinguish between the two are unable to evaluate the bearing of evidence on the theory.

Kuhn et al. concluded from their research that children are *unable* to reflect upon theories in terms of evidence and thus are unable to use them to generate predictions. They drew these conclusions from a series of studies carried out with young children, adolescents and young adults (18-26 years old) and adults (19-60 years old). As other researchers have contested Kuhn et al.'s conclusions about the capabilities of children, the activities they used with children will be examined in more detail to determine their merits and limitations.

4.1.2 Kuhn et al.'s studies of theory and evidence

One of Kuhn et al.'s projects involved the subjects in the evaluation of evidence and they were asked to examine the results from a fictional study carried out by scientists to see if there was a link between children's diet and their susceptibility to catch colds. The data (from fictional scientists) were presented sequentially and cumulatively. For example, subjects were given a series of pictures showing six children and four different types of food they ate; pictures of children holding handkerchiefs indicated these were children who had caught a cold. Different instances showing patterns of covariation and noncovariation of foods eaten with children getting colds were included. For example, Instance 1 showed that six children, with no handkerchiefs, had eaten baked potatoes, oranges, *Diet Coke* and *Granola*. Instance 3 showed a picture of another six children, with handkerchiefs, who had eaten apples, *Granola*, french fries and *Diet Coke*. The subjects were asked to indicate whether they thought the food made a difference (from 'very sure' to 'don't know if it makes a difference') and to justify their answers.

In this foods task, some of the younger subjects (age ten to eleven years old) cited theory rather than evidence when justifying their answers. They would explain why one type of food was healthier than another but they did not refer to the evidence in the pictures to explain their answers. Kuhn et al. suggest that this indicates some confusion or lack of differentiation between theory and evidence.

In another study, subjects were told that a sports company was conducting an investigation to test different kinds of sports balls. A box of sixteen sample balls was presented for the subjects' examination. The features of the balls were described orally to the subjects. The balls varied in colour (light or dark), texture (rough or smooth), size (large or small) and in presence or absence of ridges. Two baskets were then presented, one labelled 'Good serve' and the other labelled 'Bad serve'. The subjects were asked to suppose that they had carried out the investigation and that these baskets represented their results. The subjects were then asked: 'What features of the balls do you think make a difference in how a person's serve comes out?' For each variable mentioned, the subjects were asked to explain why they thought it made a difference. If subjects did not mention one of the variables they were asked: 'Does (variable) make a difference in how a person's serve comes out?'

In this sports ball task, subjects were classified in terms of the manner in which they dealt with the discrepancy between theory and evidence. According to Kuhn et al., subjects 'tended to maintain their theories and to reconcile them with the evidence either by ignoring the implications of the evidence or by evaluating the evidence in a biased manner' (Kuhn et al. 1988: 111).

Kuhn et al. concluded from their series of studies that the skills of coordinating theory and evidence were 'weak among children below adolescence, that they showed some development from middle childhood to adulthood, but that they remained at far less than an optimal level even among adults' (1988: 220). Kuhn et al..'s research sparked off a number of criticisms and further projects (Sodian et al. 1991; Samarapungavan 1992; Koslowski 1996; Leach 1999) that questioned Kuhn et al..'s findings. The criticisms of Kuhn *et al*'s research will now be examined in order to make some sense of this apparent dichotomy of views.

4.1.3 Alternative interpretations of Kuhn et al.'s findings.

Sodian et al.'s research (1991) was designed to test Kuhn et al.'s claim that when asked to determine the cause of a phenomenon:

> young children often fail to test hypotheses in a systematic way; instead they act as if their goal were simply to produce or repeat the effect, rather than to discover its causes.
>
> (Sodian et al. 1991:753)

The tasks designed for their research were aimed specifically at young children aged from six to eight years old. One task involved a story of two brothers trying to find out the size of a mouse by putting food into boxes with openings of different sizes. This was in contrast to Kuhn et al.'s research in which the same tasks were used with a range of age groups. Samarapungavan (1992) argues that the level of conceptual content of these tasks is unlikely to be appropriate for all age groups with a consequence that the evidence to support Kuhn et al.'s theory is insufficient. Tasks designed for a particular age group will give a more accurate picture of the subjects' ability and so more credence should be given to Sodian et al.'s conclusions. Sodian et al. concluded from their study that young children at the age of six *can* 'distinguish belief and evidence, and they know how to put hypotheses to the test' (Sodian et al. 1991:765).

Koslowski (1996) criticises the interpretations of Kuhn et al.'s data in some detail and she suggests that in their study, subjects who were considered to have flawed scientific reasoning were in fact demonstrating sound scientific reasoning. For example, Kuhn et al. considered that if people cite theory rather than covariation evidence to support their claims, this is flawed scientific reasoning. Koslowski puts forward a different interpretation, as she believes that treating theory as evidentially relevant *is* scientifically relevant. She explains that if covariation evidence is dismissed or not cited because the person believes it cannot be the correct explanation, then this is not flawed reasoning but a scientifically legitimate thing to do.

In accordance with Koslowski, it seems very unlikely that a child can ignore the theory they know and understand. For example, in Kuhn et al.'s study where children had to sort sports balls into those that bounce well and those that do not, the children were asked to suggest whether the size, the texture, the ridges on the ball or its colour affected the bounce of a ball. In some cases the 'evidence' given to the subjects suggested that colour covaried with bouncing and this was ignored by the children. Kuhn et al. interpreted this finding as the subject failing to recognise the hypothesis that colour could be the cause of difference in the 'bounceability' of the sports balls. An alternative interpretation is that young children are unable to follow the instruction to just look at the evidence and they reject colour because of the theory that they already hold i.e. that colour is very unlikely to affect the bounce of a ball. The view taken by this researcher is that a child is unlikely to suggest a hypothesis that they know is very likely to be wrong whereas an adult may well be able to follow the instruction to suspend their own judgement and just respond to the evidence. Koslowski has made a detailed response to Kuhn et al.'s interpretations of their data and she makes a good case for the rejection of their conclusion that children cannot distinguish theory from evidence.

This position is also held by Leach (1999) as his research indicates that children, aged nine to sixteen, *are* capable of distinguishing between theory and evidence in science but they are not all able to tackle problems which require the coordination of theory and evidence in a logical or rational manner. His work shows that a significant number of nine year olds do not refer to evidence at all when selecting and using their explanations. The findings of the research reported in this thesis suggest that children, aged ten to eleven years old, can use evidence to support their claims and make decisions, although they demonstrate a range of abilities when using evidence to justify decisions. If we accept that young children can use theories and scientific evidence to justify explanations and make decisions then an important question to consider is whereabouts in the curriculum it should be taught. The purpose of this present study is to investigate how children use evidence in order to propose some answers to this question.

4.2 Teaching the coordination of theory and evidence

The current science National Curriculum makes it clear that children should be taught how to carry out investigations and an important part of any investigation is the collection of evidence. In order to appreciate the need to collect relevant and accurate evidence children need to understand how scientific evidence can support or disconfirm beliefs otherwise they will be unable to cope with contradictory or anomalous evidence. The science National Curriculum states that children at Key Stage 1 should be taught how to explain evidence they have collected by 'drawing on their knowledge and understanding' (Sc1 2i) (DfEE 1999b). This inclusion implies that children are expected to be able to distinguish between theory and evidence.

It would appear, however, that there was no tradition in primary schools, prior to the introduction of the National Curriculum, of teaching children scientific investigations in a way that would develop their thinking skills. Indeed, the past debates in primary school science have been at a far more basic level.

Duggan and Gott (2000) hold that in the past it was assumed by science educators that pupils pick up an understanding of evidence in the course of practical work. It is clear from the literature and the research reported in this thesis that indeed, some children do 'pick up' an understanding but that there are many who do not. When considering the nature of primary science curriculum prior to the introduction of the National Curriculum it becomes clear that it has a history of contrasting approaches and change, particularly in the relative emphasis placed on scientific knowledge and scientific skills (Peacock 1997).

4.3 Initiatives in primary science prior to the National Curriculum

Primary science teaching only became a universally established part of the curriculum following the implementation of the Education Reform Act of 1988 (DES 1988). In the twenty years prior to the introduction of a National Curriculum, primary science had undergone a series of developments based on two contrasting approaches, a process-based approach and a content-based approach. The former approach had an emphasis on developing scientific skills (for example, identifying, observing, controlling variables) and the latter on the understanding of scientific concepts. Osborne and Simon (1996) give an account of some of the curriculum projects that were given funding that started in the 1960s and they chart the course of the 'content versus process' debate exemplified by different primary science projects. Two of these, the Nuffield Junior

Science Project (Wastnedge 1967) and the Oxford Primary Science Project (Redman et al. 1969) are examples that reflect the two polarised views on the aims of a primary science education. These contrasting perspectives will now be set out.

4.3.1 Primary science projects

The Nuffield Junior Science Project (Wastnedge 1967) made it clear that the aim of primary science was to develop an enquiring mind and that the learning of scientific concepts was essentially subordinate to this aim. This project heralded a move away from teaching children about facts in order to allow for the development of investigative skills. In reflecting on this project, Harlen (1993) criticises the assumption that it does not matter what the children investigate, as she believes that process skills cannot be used and developed independently of concepts and knowledge. Harlen also emphasises that concepts and knowledge cannot be fully understood without the use of process skills.

The Oxford Primary Science Project (Redman et al. 1969) was concerned with both research and development; it attempted to discover the scientific concepts relevant to the primary age range and to identify the experiences that would help young children develop these concepts. The project never became mainstream in schools and Black (1983) suggests that one of the reasons the project failed is because of the gap between the 'grand conceptual design and the activities of which the children were capable' (1983:31). Osborne and Simon (1996) put forward another possible reason: the project failed to attract a wider uptake amongst teachers because other projects fitted better into the 'predominant educational ideology of the time' as they favoured the 'learning by discovery approach'. This approach itself was not without its critics; Millar and Driver (1987) argued that a pedagogy focused primarily on the learning of processes may be 'fundamentally misguided' and they put forward two main arguments, which are summarised below:

> i) the 'empirical process which starts with observation and leads through interpretation to experimentation simply does not model children's learning'
> ii) the way children develop process skills depends on the concepts that they are bringing to the activity.

Learning process skills cannot be context-independent because children need to draw on prior knowledge and experience to develop skills. For example, children with experience of growing plants in their garden are likely to be able to suggest more appropriate methods for observing the germination and growth of seeds than children who have not had such experiences.

It might have been expected that the introduction of a statutory curriculum would have settled the debate between the content or process focus of the science curriculum. However, as Millar and Driver suggest:

> the history of science education is a recurrent cycle of periods in which the *method* of science has been strongly emphasised in the curriculum rhetoric, interspersed with periods when content features more prominently.
>
> (Millar and Driver 1987: 34)

Millar and Driver point out that this debate appeared in the UK as far back as the 1850s, so perhaps it is not surprising that the issue of 'content versus process' is still not resolved. If there has not been any agreement in over 100 years it is unlikely to be settled easily. A consequence of the absence of an agreed focus for a science curriculum has been an inconsistency in teaching approach, particularly for primary science. These inconsistencies in approach to teaching and learning are discussed in the following section.

4.3.2 The National Curriculum for primary science

When the first compulsory science curriculum (in England and Wales) was introduced in 1989 (DES 1989), process skills in science had to be given equal weighting to science content in the teaching activities and assessment used in primary schools. In more recent revisions (1995 and 1999) this obligation disappeared, possibly due to a pragmatic decision resulting from teachers' difficulties in covering the whole of the content set out. However, the changes suggest a return to the cycle of contention between proponents of process and content that Millar and Driver (1987) described and that content is, again, being given more prominence.

In the mid-1980s to the mid-1990s there was a decade of 'revelations about children's own ideas in science' (Harlen 2000: iii), particularly from the findings of the Nuffield Primary Science project, Science Processes and Concept Exploration (SPACE 1997) carried out in classrooms to explore the ideas and concepts that children hold in particular areas of science. The reports that emerged from the project document children's unorthodox ideas and provides practical suggestions for teachers to challenge these ideas (Ollerenshaw and Ritchie 1997). Yet, despite this improved understanding of how children can develop a better understanding of science concepts, there still seems to be no consensus as to the skills young people should be expected to develop. This lack of consensus is shown in the expectations of the National Curriculum as a whole and more specifically in the changing expectations of subsequent versions of the science National Curriculum orders. The lack of congruence can be shown by extracts from the documentation given to schools regarding what should be taught at Key Stages 1 and 2.

4. 4 Thinking skills across the National Curriculum

In 1999 the DfEE (1999a), published a handbook for primary teachers in England that sets out the requirements of the National Curriculum for pupils aged five to eleven. Included in the handbook are the requirements for 'Learning across the National Curriculum' and one section specifies the six key skills that are considered to be universal rather than subject-specific. One of the skill areas to be embedded across the curriculum is 'Thinking skills'. The skills identified within this section include information-processing, reasoning, enquiry, creative thinking and evaluation skills. For example, it is stated that the key skills of 'Creative thinking skills':

> enable pupils to generate and extend ideas, to suggest hypotheses, to apply imagination and to look for alternative innovative outcomes.
>
> (DfEE 1999a: 22)

If children are to be given tasks where they are expected to put forward hypotheses, their imaginations can be developed as they seek alternative interpretations. Hypotheses are beliefs that need to be tested and children can begin to appreciate how evidence needs to be collected to support or refute the different hypotheses under consideration. Despite the expectation that all subject areas should promote these skills, in practice, different subject areas have different expectations of young children. The following examples show some of the differences across subjects in how 'thinking skills' are developed.

The English National Curriculum makes group work explicit and sets out that children should be taught how to contribute to discussions, to justify what they think and to 'deal politely' with opposing points of view. In mathematics, children are expected to develop logical thinking skills and to explain their reasoning. Explanation is also a theme in the history curriculum and children are required to give reasons as to why the past is 'represented and interpreted in different ways'. Decision-making skills are included in the geography curriculum, although very little guidance is given to the teacher as to what such skills should include.

Therefore, whether young children can be expected to hypothesise seems to vary within the different subject areas. The difference is most clearly seen in when comparing the expectations of the PHSE and citizenship curriculum and the science curriculum.

4.4.1 The PHSE and citizenship curriculum

The Crick Report (Advisory Group on Citizenship 1998), discussed in chapter 3, has led to the development of the non-statutory framework for PHSE and Citizenship at Key Stages 1 and 2. The original report indicated that young children are capable of hypothesising, evaluating information and developing ways of judging what they hear, see or do as the following extract shows:

> **Proposed Citizenship Curriculum**
> **Key Stage 2**
>
> Pupils should be able to:
>
> - express and justify, orally and/or in writing, personal opinion relevant to an issue;
> - work with others in a class and gather their opinions in an attempt to meet a challenge of shared significance through negotiation, accommodation and agreed action;
> - *use imagination when considering the experience of others and be able to reflect and hypothesise* – the 'what if' scenario- on issues of social, moral and political concern in response to stories, drama or 'real life' incidents;
> - collect information about a topical or contemporary issue from a range of sources, including television and radio news, documentary footage, newspapers and new communications technologies, and recognise the different ways the sources present the information;
> - take part in simple debates and have opportunities to vote on issues.
>
> (Advisory Group on Citizenship 1998: 46-47 italics not in original)

Yet the final guidelines produced for Key Stages 1 and 2 have failed to maintain this emphasis as the following example, drawn from the Key Stage 2 Programme of Study (POS) currently in place, illustrates:

The guidance for schools for PHSE and Citizenship curriculum include the recommendations that pupils at key stage 2 should be taught to:

- talk and write about their opinions, and explain their views;
- face new challenges positively by collecting information, looking for help, making responsible choices, and taking action;
- research, discuss and debate topical issues, problems and events;
- resolve differences by looking at alternatives, making decisions and explaining choices;
- to explore how the media present information.

(DfEE 1999a: 139)

This lack of consistency reflects the confusion, outlined previously in chapter 3, about the skills of which young children are capable. The Crick Report has one set of expectations that includes the skill of hypothesising and yet, the resulting PHSE and Citizenship curriculum does not. The same confusion is mirrored in changes in the science curriculum as will now be discussed.

4.4.2 The science National Curriculum

In the current primary science National Curriculum the emphasis within skills is on the collection and presentation of data and, although children are expected to explain their observations and conclusions, the emphasis is on the use of scientific knowledge. The curriculum requires children to use evidence to draw conclusions and to decide 'whether these conclusions agree with any prediction made and/or whether they enable further predictions to be made' but it does not seem to expect children to explain *why* things did not go as they predicted i.e. to put forward a hypothesis.

The term 'hypothesis' does not appear in the text of the 1995 or 1999 documents for the science National Curriculum (DfE 1995; DfEE 1999b) though, in the earlier versions of the National Curriculum, the skill of hypothesising is quite clearly identified. For example, the National Curriculum orders in the original 1989 document state that at Key Stage 1 science activities should encourage 'the ability to plan, hypothesise and predict' (DES 1989: 3); the next version states that science activities should encourage the ability to plan and carry out investigations in which pupils 'ask questions, predict and hypothesise' (DES 1991: 3). This 1991 version also stated that at Key Stage 2 pupils should carry out activities that 'encourage the formulation of testable hypotheses, drawing on their developing knowledge and understanding'. Pupils were expected to be able to 'distinguish between a description of what they observed and a simple explanation of how and why it happened' (DES 1991: 8).

So, why thirteen years on and two revisions of the document later (DfEE 1999b), is there now no mention of formulating hypotheses? There are a number of possible explanations for the absence of 'formulating hypotheses' from later versions of the curriculum. It may be that the skill of hypothesising was considered to be inappropriate or alternatively that science education is expected to focus on other process skills. Another more cynical view is that primary school teachers found it difficult to interpret this strand in the AT1 statements and so it was abandoned. Thinking skills are, however, one of the six key skills to be handled across all subject areas and the loss of the emphasis in science is important. The significance of this change is discussed below.

4.5 The importance of the skill of hypothesising in science

The skill of hypothesising requires the use of known facts or the analysis of data to explain some phenomenon or event. Harlen emphasises that when hypothesising 'the suggested explanation need not be correct, but it should be reasonable in terms of evidence available and possible in the terms of scientific concepts or principles' (Harlen 2000: 36). However, in reality it is often difficult for a teacher to convince pupils of the value of making a hypothesis if it turns out to be incorrect. The reluctance of pupils to make explicit their tentative explanations could be a reflection of how science teaching has tended to concentrate on establishing the 'right answer'. If teachers were to expose children to situations where there is more than one possible explanation of an event, then children may be encouraged to adopt a more creative approach in making suggestions as to why something has happened. Such scenarios need not be complex; Harlen gives an example of the observation that one of two puddles left after a rainstorm dries up more slowly than another. Young children can cope with two different hypotheses for this phenomenon, for example, 1) that one puddle contained more water than the other or 2) one puddle was in the sun and the other in shade.

One primary science project, the Ginn Science Project (MacLeod et al. 1988), would support the contention that the skill of hypothesising can start in primary school. In the introduction to the project it states:

> the ability to hypothesize is related to age. All children will hypothesize but the degree of 'reasonableness' of their hypothesizing will be affected by their previous understandings and experiences and their level of cognitive development.
>
> (MacLeod, Skelton et al. 1988: 22)

However, the science curriculum as it stands does not specify that children should be expected to hypothesise. Nevertheless, the thinking and reasoning skills involved in hypothesising are skills that are important to develop in children. For example, the skill of hypothesising includes the ability to give reasons for opinions, to use precise language to explain what they think, and being make predictions informed by evidence. This study proposes the view that children can indeed be taught elements of these skills in the primary school through argumentation activities. It is also suggested that, although there is considerable potential to develop children's argumentation skills in the National Curriculum in general, there is currently no evidence of a coherent approach across the different subjects as has been illuminated with reference to PHSE and Citizenship and the science curriculum. The following section now examines where in science, opportunities to develop the skills of argumentation are missed.

4.6 Teaching argumentation skills in science

The current National Curriculum identifies the scientific skills children at Key Stage 2 should be taught in the Programme of Study (POS) 'Sc1 Scientific Enquiry'. This POS is divided into two sections:

1 Ideas and evidence in science
2 Investigative skills, including 'Planning', 'Obtaining and presenting evidence' and 'Considering evidence and evaluating'.

When the requirements outlined in these sections are examined it is clear that the science National Curriculum does expect children at Key Stage 2 to consider what sources of information to use and what kind of evidence to collect in their planning of investigations. However, the planning is directed at finding the answers and there is no indication that evidence might be inconclusive. If evidence always proves the theory to be correct children will not appreciate that evidence can be misleading and may be interpreted in different ways. If children become accustomed to examining evidence that supports a specific concept it is unlikely that they will understand that it was through the evaluation of conflicting evidence that concepts were developed in the first place.

Despite the relatively low expectations in the POS at Key Stage 2 for science there is no reason why the skills of interpreting and evaluating evidence cannot be taught in primary schools. Science education, in fact, provides a good context for the development of these skills. Harlen (2000) is quite clear that this learning process can start in the primary school. She states that primary teachers can encourage children's development in interpreting by:

- providing time and opportunity for children to identify simple patterns or relationships which bring together separate findings;
- ensuring that results of investigations are always discussed and that what is found is compared with what was predicted;
- helping children to treat their interpretations and conclusions as tentative.

(Harlen 2000: 189)

If we accept that science education can provide opportunities for children to develop the skills of argumentation through the evaluation of evidence and the justification of ideas and interpretations, then we need to consider the reasons why such opportunities are so often overlooked. The way that primary teachers apply the science National Curriculum requirements will now be explored further.

4.7 Missed opportunities in the science National Curriculum

In England, teachers in state schools are required by law to follow the National Curriculum and an examination of its contents will help to illustrate possible reasons why teachers are not taking opportunities to develop argumentation skills. In the POS for the current science National Curriculum (DfEE 1999b) at Key Stages 1 and 2, the emphasis is on pupils collecting their own evidence and evaluating this evidence by considering whether the tests they make are fair. This process has been stated very clearly in the POS of successive versions of the National Curriculum and as a result the teaching of the 'fair test' has been fully adopted into primary school science (Watson et al. 2000).

However, in the current curriculum there is no reference to the evaluation of evidence to see whether it can *justify* the predictions or conclusions made. Failure to emphasise that evidence may *not* be conclusive reinforces the attitude that science has the 'right answers'. This is a position also held by Duggan and Gott (2000) who, in their criticism of the present UK science curriculum, conclude that it overlooks the notions of scientific uncertainty, probability and risk. As discussed in chapter 2, these are skills that are critical to the public understanding of science.

Creative teachers are, however, not necessarily restricted by the demands of the National Curriculum (Woods 1995) and teachers with confidence in their understanding of science process skills may consider that hypothesising *is* part of the skill of considering and evaluating evidence. There are a number of reasons why primary school teachers vary in their confidence to teach science (Watt and Simon 1999); factors that could influence confidence include teachers' own subject knowledge, the way they were taught science themselves and their interpretation of the National Curriculum requirement. The next section will explore these issues further.

4.8 Teachers' experiences of teaching primary science

At the time the National Curriculum was introduced in 1989, most primary school teachers had little experience of teaching science and many had a limited science education themselves, particularly in the physical sciences (Peacock 1997). Peacock refers to research that evaluated the success of the teaching of primary science and concluded that science teaching was:

> often characterised by frequent errors of fact; tight teacher control leading to aimless activity; missed opportunities to elaborate on pupils' responses; and explanations and discussions which compound pupils' own misconceptions.
> (Peacock 1997: 6).

However, he reports that there was encouraging evidence to show that where teachers did have background knowledge and confidence in the subject, the science teaching was more in line with 'accepted notions of good science practice'. As referred to earlier, one of the themes of good practice in science teaching that has progressed in England and Wales has been the inclusion of investigations, particularly those tasks that have developed children's understanding of a 'fair test' (Watson et al. 1999).

Despite the introduction of basic investigative work in the primary classroom, Watson et al. argue for the use of a wider range of science scientific skills to be deployed, for example, where the pupils collect evidence to support or refute an idea. At present, the selection of topics teachers can choose from is very limited. Practical work does have the potential to develop children's ability to interpret and evaluate evidence, yet little opportunity is given to the practice of this skill; much of the practical work found in schools at present is confirmatory in nature and produces data which does not challenge the children's ideas or encourage them to question their evidence.

One must question why many science teachers are failing to address these skills through their teaching. Cross and Price (1996) suggest that teachers themselves have been socialised by their own science education where:

> the sheer quantity of factual knowledge and idealized experimental work demanded of students acts to create an aura of certainty and predictability of knowledge.
>
> (Cross and Price 1996: 321)

Certainly, this may be part of the problem but it can also be argued that the requirements of the science National Curriculum oblige teachers to focus on the elements that will be assessed in the Standard Attainment Tasks (SATs). SATs have traditionally focused on assessing subject knowledge rather then scientific enquiry skills. Moreover, the National Curriculum has stifled teacher creativity and has led to a narrowing of the teaching and learning methods deployed. The report from the Primary Assessment, Curriculum and Experience Project (PACE) (Pollard et al. 2000), suggests that pressure on teachers to cover the content of the curriculum may cause them to concentrate on developing children's recall of subject knowledge at the expense of understanding how such knowledge has been developed and what evidence there is to support established scientific ideas.

Another result of the focus on achieving targets for SATs has been the change from small group work to whole-class teaching (Pollard et al. 2000). The significance of this change will now be explored, as group work could provide the context for the development of investigative skills.

4.9 Teaching methods in primary science

Group work in science teaching, particularly when planning and carrying out investigations, enables children to share ideas, explore understanding, propose possible courses of action and make decisions. Children making suggestions in a group communicate in a safer environment than in a whole-class situation; they can challenge each other's ideas more easily as they are in control of the discussion and therefore have more time to formulate responses (Fairbrother 2000).

If children feel more confident to contribute when the teacher is not involved in the discussion then they will have more opportunity to hear alternative viewpoints and pursue the justification of claims. If children working in small groups are expected to justify opinions and decisions with reference to data, then they will be developing their skills in the use of evidence. With an emphasis on the teaching of investigative work, primary science has an opportunity to promote collaborative group work that will involve children in discussion, the formulation of arguments and the evaluation of evidence.

The Crick Report (Advisory Group on Citizenship 1998) suggested that children should be encouraged to challenge each other. In science, children could be taught not only *how* to challenge in an acceptable way but also how to challenge the quality or source of evidence another child uses to justify an opinion. Such evidence could be information found in a book, the results of an experiment or it could just be the comment of a friend. Examining claims to see if they are supported by reliable evidence is a task that young children can manage. As they grow older they can interrogate claims based on insecure evidence, such as where data have been selected to bias the results or where the sample size is very small. Science can provide an excellent platform for the development of these skills when teachers address 'considering and evaluating evidence' in the POS for Sc1.

The non-statutory information in POS Sc1 of the current National Curriculum (DfEE 1999b) indicates that group work is a recommended teaching strategy in science and the guidance suggests that at Key Stage 1 children should work together to collect evidence and share ideas. At Key Stage 2, they are expected to carry out investigations 'on their own and with others'. Yet, as will now be discussed, group work is not a strong feature of Key Stage 2 classrooms and so the opportunity for children to work together collaboratively is limited.

4.10 Group work currently used in primary schools

There seems to be a divergence of views as to the amount of group work that occurs in schools. Harwood (1995) reports that group work is generally accepted as an essential part of today's classroom practice. However, as discussed earlier, more recent research by the PACE project paints a different picture (Pollard et al. 2000). The PACE project examined the changes in classroom practice in primary schools since the introduction of the National Curriculum. The findings show that group work was only significant in Key Stage 1 and, that in Key Stage 2, group work was not considered by the teachers to be effective at 'covering the ground'. The PACE findings indicate that the introduction of the National Curriculum has resulted in more whole-class teaching and less group work in the primary classroom. The report refers to comments by children on their perspective of science that indicate that little group work takes place in science, particularly in Year 6. Pupils find science 'boring' as they spend a lot of time 'writing things down'. The PACE authors suggest that the pressure on children to record and recall information has 'killed their enthusiasm for the subject'.

Though these trends have been reported by the PACE project, there are other researchers developing the use of collaborative group work in primary classrooms, with some success (Mercer 2000). A possible way forward to rekindle children's interest in science and, at the same time develop investigative skills, would be to introduce group discussions and argumentation into scientific activities. If teachers come to appreciate how argumentation can develop children's skills in, for example, the consideration and evaluation of evidence, they may be more confident about introducing such activities. However, there is currently limited research relevant to the primary school age range that would enable teachers to assess the merits of using more collaborative work in the classroom.

Conclusion

It has been established that group work should be an essential part of not just primary school practice, but also a key part of the science curriculum as in group work children can develop their skills in using evidence to justify their decisions. Successful group work should enhance pupils' thinking and reasoning skills as they have to articulate their ideas and defend them in the light of challenges from other group members. If we want children to develop the skills to make rational decisions based on available evidence then we need to know more about their capabilities in these skills. Research has shown that older children can benefit from working in groups as they justify alternative viewpoints but we have to question how younger children benefit from such activities. When children are presented with a decision to make and they are given information to help them make up their minds, do they use this information? Do they listen to one another's points of view? Do they justify their claims or challenge opposing views? The next chapter will focus on how this study was designed to answer these probing questions.

Summary

In this chapter the case has been made for the teaching of thinking and reasoning skills to become better defined in the primary school curriculum. Although research about children's thinking skills reach different conclusions about children's abilities to think, particularly in the skill of coordinating theory and evidence, it has been argued that children are capable of these skill but that these skills need to be taught more explicitly in the curriculum. It has been suggested that thinking skills could and should be developed through a range of subjects in the primary school. However, as different areas of the curriculum appear to have different expectations of young children it appears that we need to be clearer about young children's capabilities. A particular area of dispute is the children's ability to hypothesise and to use evidence to justify their reasoning. It has been argued that developing skills of argumentation is one way to develop children's critical thinking skills and that science education has a particular role in the development of such skills. The role of group work in this skill development has been discussed and it has been proposed that group work in science needs to be encouraged so that children can learn how to argue, to challenge each other and to appreciate the need for evidence in supporting and refuting claims. In the following chapter it is explained that we need to know more about how children use evidence when they argue so that we can plan the teaching of these skills appropriately. A method to demonstrate how children use evidence has been developed and this method is presented in the next chapter.

Chapter 5 The Research Project

5.0 Introduction

The previous chapters established that science education could play a more important role than it currently does in preparing young people to think and reason. As children need to be prepared to cope with choices they will have to make in the future, it is important to help them appreciate how decisions can be made and what forms the basis of their decisions. In Chapter 4 research evidence was used to argue that science education could take a more prominent role in preparing children to think, reason and make decisions in the primary school. Moreover, the science National Curriculum expects children to be able to consider and evaluate evidence at a young age.

As explained in chapter 1, the research for this thesis was designed to find out how children use evidence when making decisions. This chapter explains how the research methods used to investigate this issue were selected. First, the overall strategy is discussed and the approach adopted in the research is justified. The need for a developmental, pilot phase for the research is described and details of how the findings of the pilot study informed the method for the main study are given.

5.1 The research aims

The arguments presented in chapters 2 to 4 suggested that children need to experience an education that equips them with the necessary thinking skills to take part in democratic decision-making as adults. It was also suggested that science education could, and should, foster thinking and reasoning skills through argumentation so that children develop the skills that enable them to:

- critically review available evidence;
- justify claims by reference to evidence;
- evaluate evidence.

These skills will help children to make decisions about issues where there may be conflicting or inconclusive evidence, as is the case in many current issues that concern people today. Science education can have a particular role in the development of argumentation skills through the scientific enquiry aspect of the National Curriculum. As discussed in chapter 4, there is at present little research on children's abilities to argue and use evidence in scientific decision-making activities. If teachers are to embark on developing these skills in children they will need to know more clearly what children are capable of in the context of decision-making activities. Once the range of competence children have in using evidence is established, teachers can identify relevant targets and provide suitable activities to develop children's skills further.

The main purpose of the research reported in this study is to find out how children use evidence in decision-making activities and to identify the range of abilities found in children when they reach the age of ten to eleven years old. The following section explains in more detail how these aims were addressed through the research.

5.2 Initial questions about the research method

If teachers are to develop children's skills in using evidence then they need to consider:

- what sort of activities to provide;
- how to manage the activities, for example group work or with children working independently.

5.2.1 Questions concerning the types of activity

For children to demonstrate their skills in using evidence they need to work on activities where they explore evidence that may be presented in a number of different formats. For example, children may have to explore data they have collected during a science investigation and use this data when drawing conclusions. Do they refer to the data to support their conclusions? What happens when the data do not support their hypothesis?

How do they cope with conflicting data? Finding answers to these questions will help us to understand the importance children place on scientific evidence.

Teachers also need to know how children use evidence to make choices for which there could be alternative yet equally acceptable answers. As discussed in chapter 2, socio-scientific problems may have alternative solutions rather than one correct answer alone, yet people often have to make a choice one way or another. Using activities that provide children with a number of possible decisions means that children have to explore evidence to discuss the advantages and disadvantages of the possible options. Such activities might include debates about socio-scientific issues where children may have very different points of view; for example, children may have very contrasting perspectives on whether it is acceptable to keep pets in the classroom. Consequently, we need to know if children are capable of considering views that differ from their own and whether they can defend their own positions using evidence.

5.2.2 Questions concerning the management of activities

As the views of children may be constrained by their physical ability to write and the time available to do so (Bradley 1996), children can express their reflections on the evidence and show how evidence has led to a decision more easily in discussion.

As children find description easier than explanation (Cork and Vernon 2000), they can describe *what* happens but activities need to be designed that encourage children to consider reasons as to *why* things happen. Therefore, it is important that children are faced with a range of possible options or choices. If they have to justify why they chose one option rather than another it means they have the opportunity to weigh up the evidence for all possible choices. Working in a group means that children are more likely to have a plurality of views and will have more opportunities to explore different ideas than if they were considering an issue on their own.

Teachers need to know the capabilities of each child so they can make judgements about the progress made and plan future ways for further skill development. It is important, therefore, to know whether children demonstrate the skills, of which they are capable as individuals, when they are working in a group. For instance, some children may not express their views in a group for a variety of reasons and yet be quite capable of justifying their claims in an alternative situation.

With these pedagogical concerns in mind, the following research questions were formulated:

- How do children make use of evidence to justify the decisions they take when they work in a group?
- How do they make use of evidence to justify the decisions they take when working as individuals?

These two key questions formulate the research problem. In order to arrive at the answers through research, more specific questions need to be addressed and these are given in the next section.

5.3 Further research questions

More specific research questions are listed in Table 5.1, overleaf, and their relevance to this research will be discussed briefly below.

Table 5.1 The research questions, which framed the enquiry into how children use evidence

When groups of children are presented with decision-making activities involving the use of evidence:

a. Do they explore all the evidence made available to them?
b. Do they use evidence to support and justify their choice?
c. Are there any differences between the ways they use evidence presented in different formats?
d. Can the way they use evidence be identified as different levels of performance?
e. Do they demonstrate different levels of performance when working as individuals rather than in groups?

5.3.1 Do children explore all the evidence provided?

A number of pieces of evidence may be used to support a decision and the research sought to find out whether children review all the available evidence or whether they simply pick out pieces that support their own viewpoint. The research also aimed to find out whether they consider the advantages and disadvantages of the choices they make or if a limited number of alternatives are examined.

5.3.2 Do children use evidence to support and justify their choice?

The research set out to determine whether children use the available evidence to support and justify their claims during a discussion or whether they make unsubstantiated claims. Another strand of the research was to discover whether children use sources of evidence other than the information provided for them.

5.3.3 Are there any differences between the ways children use evidence presented in different formats?

In primary science children are expected to use tables, charts, line graphs and diagrams to present results and they are required to evaluate these results and use them to draw conclusions (DfES 2002). Typical activities in the primary science classroom involve children collecting numerical data, for example, measuring how far a sycamore seed can fly or how the temperature changes as water cools down in different containers. Decisions may have to be made using evidence presented in different ways and the research set out to determine how children use evidence presented both in familiar and unfamiliar ways. Many worksheets used in primary science require the children to record their results in tables and answer the question 'What do your results tell you?' Though information presented in pictures and in descriptions may be more familiar to children when working in other subject areas, such as history, it is not common in science.

For teachers to be able to plan for progression in the skills of interpreting evidence, they need to know whether children find it easier to evaluate evidence presented in one format more than another and whether these skills are linked to the subject matter. The research sought to examine children's capabilities in using evidence presented in a range of formats that might be used in the science classroom.

5.3.4 Can the way children use evidence be identified as different levels of performance?

If we expect teachers to enhance children's skills then there must be some way of measuring improvement and assessing progress. Thus an assessment tool needs to be developed. At GCSE level there are criteria for judging students' skills in 'Experimental and Investigative science' (Sc1) and examination boards give mark descriptions for teachers to grade students' skills in obtaining evidence, analysing evidence and evaluating evidence (Hicks 2001). As proposed in chapter 3, until teachers know the range of abilities it is difficult to plan for progression in the development of such skills. Therefore, it is important to identify the levels of performance in discussing and using evidence that are relevant to the abilities of children.

5.3.5 Do children demonstrate different levels of performance when working as individuals rather than in groups?

For teachers to plan activities that both engage and challenge children they need to know what range of abilities to expect in the ways children use evidence. For example, do children perform in similar ways or do they have a range of skills? To inform the teaching of these skills in children, the research looked at ways in which different levels of skill in the use of evidence can be judged for individuals as well as for a group.

5.4 The research approach

The approach adopted in research must depend on the focus of the research and both quantitative and qualitative approaches can be used. Many researchers (Schwandt 2000; Silverman 2000; Denscombe 2003) argue that a mixture of methods can be adopted as they can provide alternative insights into the research. Denscombe contends that the distinction between quantitative and qualitative research is far from 'watertight'. He suggests that the assumptions behind the two approaches are often shared or overlap and that good research tends to use parts of both approaches. The research reported in this thesis adopted essentially a qualitative approach but with some elements of quantitative analysis of the data. The reason why this mixed approach was adopted will now be explained.

5.4.1 The qualitative nature of the study

The research questions that concern this study, listed in section 5.1, were framed to find out more about the way children use evidence and argue in decision-making activities. The method was, therefore, designed to find out *how* children used evidence and how children's skills at evaluating evidence *differed*. Thus, the research was designed to:

- find out more about how children use evidence;
- find out how children use evidence in activities that could be used in the classroom;
- involve detailed observations of a small number of groups of children using video and tape recordings;
- develop a technique for analysing the discourse of children's discussions.

The overriding aim has been to discover how children react and interact when presented with situations where they need to demonstrate how they use evidence. These issues were investigated with a small number of groups of children. How these characteristics of the research lend themselves to a qualitative approach is now explored.

The focus of the research was not designed to test a theory about how evidence is used by children, nor was it designed to measure the number of children who used evidence. It was to find out more about the way in which children use evidence as they engage in decision-making activities, through an interpretation of their interaction. This interpretative approach is more a feature of qualitative research rather than research that is predominately quantitative, such as research that is often used to test hypotheses by analysing large datasets.

Obtaining data that answer these research questions necessitated close observations and transcript analysis of children working together on decision-making activities so that an understanding of how they use evidence together could be developed. The resulting data exemplify what a teacher could observe in classroom activities related to the science curriculum, illustrating what teachers might expect children to be able to do or, as Miles and Huberman (1994) put it, 'the research got a strong handle on what 'real-life' is like'. Research that represents real-life situations may have more credence for teachers as they can easily see the relevance of the findings to their own classrooms.

As Burns (2000) contends, qualitative methods attempt to capture and understand the meanings of events whereas quantitative methods count and measure events. The detail required for the analysis of individual children's responses limited the research to a small-scale project and demanded a qualitative style of research, that tends to be associated with descriptive, small-scale studies (Denscombe 2003).

There was not an established method that could simply be adopted for this research, so the design was developed and refined during the study. As Silverman notes, the focus of research can, in practice, change because of the 'subtle interplay between theory, concepts and data' (Silverman 2000: 63). For this study, the design emerged from the interplay between the theory about children's abilities in determining and using evidence as outlined above, and the data derived from the first attempts at working with the children in a pilot study. Symon and Cassell (1998) explain how researchers using qualitative methods may create, test and modify the data analysis in an iterative process and so data gathering might continue as the analysis takes place. In research where the analytical tools have already been devised this flexibility is lost. A qualitative method was, therefore, believed to be the more suitable method for the research reported here, but some quantification of the data was also employed.

5.4.2 The quantitative component of the study

The quantitative aspects of this research are to be found in some of the analysis of the data. Although most of the analysis is interpretative, some of the data were treated using simple quantitative analysis, for example, when analysing *how much* of the available evidence the children used. A quantitative approach was also used to explore how many claims were justified by the children. In chapter 6, a fuller description of how the analytical tools were devised and applied is provided.

5.5 The research design

The research was organised into two phases comprising a pilot study and a main study. The pilot study took place over one academic year (1998 - 1999) and the main study was carried out in the following year. Dates of visits to the schools used in the pilot and main studies are given in Appendix 1.

The exploratory nature of the pilot phase was necessitated by the lack of any substantial literature providing activities that facilitated children's use of evidence in decision-making activities. Activities had therefore to be developed afresh or by adaptation. Essentially, the purpose of the pilot study was to try out the activities and research approach and subsequently refine research methods and analytical techniques that would enable the research questions to be answered. At the end of the pilot phase, the data were examined to determine which activities elicited children's discussion about evidence as they came to a decision.

The results from this preliminary work were also used to design and refine the analytical frameworks.

5.5.1 An overview of the pilot study

At the start of the pilot study there were six major queries to be addressed with regard to both the research questions and the techniques used to resolve them. These questions are listed in Table 5.2, overleaf.

Table 5.2 The questions posed for the pilot study

a. Are the decision-making activities suitable to demonstrate how children use evidence?
b. What sample of schools should be used in the research?
c. What type of role should the researcher adopt?
d. What is the most effective recording (video and/or audio) technique?
e. What is the appropriate number of children to have in a group?
f. What analysis techniques reveal how the children use the evidence?

In order to answer these questions the pilot study tested eight different activities in four pilot schools. The activities used are listed in Table 5.3 with a brief description of the nature of each activity; more details of these activities are given in Appendix 2. Activities were used with small groups of children, where interactions were video recorded. The researcher took a teacher/helper role whilst observing the children's discussions. The teacher/helper role involved explaining what the children had to do for each activity and meanings of words to the children or answering their questions when required.

As Table 5.3 shows, some of the activities were only used once. These activities proved to be unsuitable for the research, as they did not show how children used evidence in their discussions. The reasons for this are discussed in section 5.6. The activities that did seem appropriate were used a number of times with different groups in order to find out if adaptations of the activity were necessary. The research methods and analytical techniques were developed as a result of the findings to the questions set out previously in Table 5.2.

Table 5.3 The pilot study activities

	Activity	Number of trials	Description of the activity
1	Shoes activity	1	Children tested the friction of soles from different shoes.
2	Pulse rates activity	1	Children measured pulse rates before and after activity.
3	Electricity activity	1	Children made simple electric circuits.
4	Coins activity	1	Children explored the magnetic properties of different coins.
5	Cups activity	6	Children investigated different properties of three different cups.
6	Marbles activity	2	Children made decisions about the correctness of data.
7	Bats activity	8	Children made a choice about what to do about bats in a roof.
8	Gerbils activity	4	Children made a choice about which home to buy for some pet gerbils.

To summarise, the pilot study findings showed that:

- the Cups, Marbles, Bats and Gerbils activities were the most suitable but each required some adaptation as will be described below;
- schools, in the main study must be prepared for the activities additional to the school's teaching programme for science;
- the dual role of teacher/researcher did not cause any difficulties for the children;
- recordings of discussions needed to be outside the classroom;
- a group size of four children was most suitable.

A brief overview of the main study will now be given and then the method designed for this research will be described in more detail.

5.5.2 An overview of the main study

The data collection for the main study took place from September 1999 to April 2000 and involved four different activities. These activities were the:

- Finding a home for gerbils;
- What can be done about the bats?
- The best cup for a picnic?
- Whose conclusion is correct?

Hereafter, these four activities will be referred to as the Gerbils, the Bats, the Cups and the Marbles.

Three different schools were used, two in London boroughs referred to as: St Anne's Primary School and Woodstreet Junior School, and the third school, Castle Hill School, was in Surrey. Two groups from Year 6 in the London schools took part but only one Year 6 group from the Surrey school took part. The same four activities were used for all five groups of children. The reason why these activities and these schools were selected will now be explained.

5.6 The activities

Of the eight activities used in the pilot study, four were rejected (Shoes, Coins, Electricity and Pulse rates) because the evidence presented was very limited and the children had little to debate before they made a decision. Moreover, in the case of the electricity activity, no real decision had to make as they were just making simple circuits. The reasons why these activities had been included in the pilot were to see if activities, that were part of a school's teaching programme, could be used in the main study. As previously discussed, these activities did not engage the children in argumentation and it became clear that specific activities would be required.

The four activities that were selected (Cups, Bats, Gerbils and Marbles) had been developed specifically for this research as will be explained below. These activities engaged the children in extended discussion about the meanings and implications of the evidence and had led to different choices being made. The pilot study showed that the activities would need to have the certain characteristics if they were to answer the questions outlined in section 5.3. It was concluded that the activities suitable for this research would need to:

- provide alternative choices;
- relate to children's interests;
- present evidence in different formats.

To find out how the groups of children used evidence to justify choices and how much of the evidence the children explored, the activities needed to provide legitimate alternatives. If the decision was very obvious to the children, there would be no reason for them to explore all the evidence. The evidence also had to be presented in a form that was accessible to the children in terms of language, presentation and amount of evidence provided.

The activities used had to relate to the children's interests and knowledge if they were to be able to demonstrate certain skills (Samarapungavan 1992). Samarapungavan is critical of experiments, such as those used by Kuhn and her colleagues (1988) that rely on the same set of tasks to test the skills of children, lay adults and scientists as it is highly unlikely that the conceptual content of the tasks would be suitable for all three groups. The tasks for this research had to be realistic for children aged ten to eleven years old and so were set in the context of a Year 6 classroom or in a situation that was sufficiently familiar for the children to be able to use evidence to support and justify their decisions.

To find out if there was any difference between the ways children use evidence when presented in different formats, activities had to be devised that presented data in a familiar format such as that found in their own science lessons, and also in ways that were not familiar. Two activities that included evidence presented in the form of information and pictures were adapted from published materials found in the Science and Technology in Society for Key Stage 2 Science Project (SATIS 1993), that were devised by Association for Science Education (ASE). However, the activities where evidence was presented in the form of tables of figures had to be designed *de novo* as no published materials suitable for the primary age group were found. At the time this research was carried out, there were no materials on data handling for primary science and although some data handling activities designed for older children were found (Pritchard 1989), it was not possible to adapt them for a younger age range. This was because the subject matter was not appropriate for younger children as it involved scientific concepts too advanced for the abilities of this age group.

If the children were to carry out investigations and discuss their own results, rather than have results given to them, it would be difficult to ensure the activities were the same for each group. However, it is more difficult for children to engage with results they have not recorded themselves, as they need to understand *how* the results were recorded. In one of the pilot schools, to test if children could engage with data they had not collected themselves, the children worked with the results recorded by the pupils in another pilot study school. In order to make the evidence more accessible, the children were given the 'story' behind the results they had been given; they were told the names of the children who had carried out the investigation and were given the cups that had been used. They also were given details about how the investigation had been carried out. The groups of children working with the results in this way were found to engage in the discussion and so this procedure was adopted in the main study. However, there were some changes required for each of the activities and these will be discussed for each individual activity.

5.6.1 Activity 1: Finding a home for the gerbils (Gerbils)

This activity was adapted from the SATIS materials (SATIS 1993) from Book 1, Unit 5 *A Home for Gerbils*. The children were asked to evaluate and select a home suitable for some gerbils. In the pilot study, the children were given pictures and descriptions of five homes suitable for housing small mammals (see Appendix 2). This activity was selected for use in the main study as the pilot study had demonstrated that it was suitable for showing how the children used the evidence in different ways. If the children had used evidence in the same way it is likely that they would all have chosen the same home; as it was, different groups chose different homes.

In the main study, reductions were made to the amount of evidence as the information sheets required a great deal of reading and led to repetition in the discussions. The exercise was adapted by reducing the number of choices from five to three. The materials used for the main study are given in Appendix 3. Choosing between three homes still provided plausible alternatives and engaged the children in discussion but the amount of reading was reduced. Consequently, the children were given pictures and descriptions of just three homes that still presented them with a choice between what was best for the gerbils and what would be the easiest home to maintain.

For ethical reasons, the choice of home was discussed with the children at the end of the activity. One of the homes is recommended by the RSPCA (Dunphy et al. 1993) as it is most like the natural environment of a gerbil. The requirements for a gerbil home were explained to the children. Should the children be faced with such a choice in the future when looking after a gerbil, it is important that they understand the full implications of their choice.

5.6.2 Activity 2: What can be done about the bats? (Bats)

This activity was also taken from SATIS materials and again adaptations were made to the original task from Book 3, Unit 5 *Bats in Conflict* (SATIS 1993) following the findings of the pilot study. This task was devised to demonstrate how children would use information presented as a set of cards (see Appendix 2) giving children some facts about bats.

In the pilot study, the children were asked to talk about their views on bats, which revealed their existing ideas and opinions and then they were presented with a Problem Card (see Fig. 5.1) devised by the researcher, which stated that:

Figure 5.1 The Problem Card

There are bats in the roof of the library. The bats' droppings are spoiling the books and ruining the wooden floor. Something has to be done. What do you think?

The children wrote down their responses to the problem as an individual plan and then discussed their plans with each other in order make a joint plan. Once this joint plan had been completed the children were then presented with the 'evidence' they had to explore. The evidence was in the form of *BAT FACT?* cards taken directly from the original task. There were sixteen cards with equal numbers of true and false statements and the cards were presented folded in half with only the *BAT FACT?* side showing (see Fig 5.2).

Figure 5.2 A *BAT FACT?* Card

BAT FACT ?   Bats can get tangled in your hair.   ***--------fold card here-----***   **FALSE**   Bats use a system called echolocation to find their way in the dark. It works very well and they never fly into peoples' hair

The children were asked to read the fact (For example, *Bats can get tangled in your hair.*) and to decide whether the information would be relevant to their plans. They then had the opportunity to revise their original plans. The revised joint plan revealed whether any changes were made as a result of reading the *BAT FACTS?* cards and whether children used the 'evidence' to support any changes made. Finally, the children were asked to tell each other their views on bats again to establish whether the evidence had caused them to change their original views.

In the main study, as in the pilot study, the children were presented with the same problem card for which they first suggested individual solutions but the part of the activity where the children were asked their opinions about bats was removed. This was because the data from the pilot study indicated that asking children about their opinions did not reveal how they had used the evidence to make their decisions.

For the main study, it was decided that the children should again record on paper their ideas about what to do about the bats, firstly as individuals and then as a group after discussion. This initial individual response ensured that all the children had something to contribute to the discussion. Also, as they had made a preliminary decision, the 'evidence' presented to them would be more meaningful as they wanted to see if they had made the 'right' choice.

Changes were also made to *BAT FACT?* cards following a consultation with the Education Officer for the 'Bat Conservation Trust'. This letter is included in Appendix 4. She had suggested the vocabulary used in some of the cards should be changed, for example, one card said 'Bats are fragile.' and the Education Officer suggested the 'Bats are vulnerable.' would be a better description. The number of cards focusing on the legal aspects was reduced as the Education Officer thought the legal aspect had been overplayed in the original resource. This was revealed in the data where some children discussed the legal aspects (For example, '*It is against the law to sell a bat.*' and '*It is against the law to possess a bat.*') to the exclusion of many of the other facts presented to them on the cards. The number of cards was reduced from sixteen to twelve as the pilot study revealed the children spent a long time reading so many cards. The cards used in the main study are provided in Appendix 5.

For ethical reasons, the action plan was discussed with the children at the end of the activity. Bats are protected by law and the children needed to recognise whether their proposed actions were feasible and also that it was important that they understood the full implications of their decisions.

5.6.3 Activity 3: The best cup for a picnic (Cups)

This activity was carried out in two different pilot schools. As explained in section 5.6 the activity for one pilot school was designed as an investigation carried out by the children themselves. The researcher planned and taught a lesson to the whole class where the children devised ways of testing the properties of three different cups, a thin plastic cup, a thick plastic cup and a cup made from glass. They investigated the stability, insulating properties and the strength of each cup. This involved testing which cups were knocked over easily by a pendulum, whether the temperature of the water changed when left in the cups for five minutes and finally, what happened to the cups when a heavy weight was placed on top of them.

Two sample groups were taken outside the classroom to record their discussions as it had been established that this facilitated better recordings than inside the classroom. Of the two sample groups, one investigated the insulating properties of the cups, and the other carried out the remaining two investigations. Both groups then shared their data with each other. A week later the children were given the data they had recorded and were asked to choose one cup suitable to take on a picnic. These data are given in Appendix 2. These questions were designed to see which pieces of evidence about the cups the children used to make their decisions and to see if they used:

a) the data they had recorded;

b) other information they had been given (the cost and 'weight' of each cup); and/or

c) any other information they had talked about in the discussion.

The findings from this activity in the pilot study showed that as details of the cost of each cup had been included, some groups focused on the issue of money and did not take account of the data about the properties of the cups. The children's discussion focused on value for money as the following extract illustrates:

Extract 1

69. **Stuart**: So it's a thick plastic one?
70. **Kylie**: Because it is …
71. **Stuart**: Cheap!
72. **Janet**: It's not the cheapest, isn't it?
73. **Stuart**: Yes, but it is cheap.
74. **Kylie**: It's quality, it's good quality.
75. **Janet**: It's quality for money.

To encourage a more scientific discussion the details of the cost of each cup were removed from the table of results used in the main study. The information given to the children included the results of an investigation about the properties of the cup, for example, whether the cups knock over easily and how much the cups weigh. The data about the cups used in the main study are included in Appendix 6. Thus the children were not faced with a choice of a cup that was best value for money (as the price had been excluded) but a cup that had the most suitable properties. In this activity there is no 'right' answer and there are no ethical issues concerning the choice of cup made.

5.6.4 Activity 4: Whose conclusion is correct? (Marbles)

This activity was to be designed to provide experimental data for interpretation suitable for Year 6 children. It was based on an activity designed to investigate the effect of friction on the speed of a rolling marble. In this activity the children were presented with three different accounts of a scientific investigation carried out by a group of (imaginary) Year 6 pupils called Katie, Winston, Rebecca and Hari, along with the data these pupils had recorded (see Appendix 7). These data recorded the time noted for a marble to roll down a tube covered in two different surfaces; one tube had ridges of glue down its length and the other was covered with bubble wrap. Models of the tubes with the appropriate covering were also given to the children. The accounts of the children included some anomalous data as the following summaries show:

> Account 1 was written as a joint report by Katie and Winston. They had carried out the test accurately and had provided a detailed account that showed they had carried out a 'fair test'. Their data indicated that the marble rolled down the glue-ridged tube faster than down the bubble-wrapped tube.
>
> Account 2 was written by Hari. Although he had carried out his investigation with Rebecca his account lacks detail and it is not clear whether they had carried out a 'fair test'. His table of results and his conclusion indicated that the marble rolled faster down the tube covered in bubble wrap.

> Account 3 was written by Rebecca. Although she had carried out her investigation with Hari, and provided the same set of data, she concluded that the marble rolled faster down the tube with glue ridges.

The children were asked to read the three accounts and decide whether the marble would roll faster down the tube with glue ridges or down the tube covered in bubble wrap. The aim of the activity was to see:

- if the children could recognise the anomalies in the results and conclusions;
- whether they could provide an explanation to account for these anomalies;
- if they used evidence from the children's accounts of the investigation to justify their explanations.

The only change made for the main study was that the data were presented with the accounts rather than on separate sheets. The children in the pilot study had suggested this change as they had found it difficult to match the data with the correct account of the investigation. The materials used in the main study are given in Appendix 7.

The pilot study showed that the children easily identified the anomalies in the accounts and the discussions centred on justifying how these anomalies had arisen. In all cases, the account of Katie and Winston was judged to be correct, the marble should roll down the glue-ridged tube faster than down the bubble-wrapped tube and the design of the activity intended that this interpretation should be made as is now explained.

Account 1 (see above) shows that Katie and Winston had carried out a 'fair test' and so children reading this account should assume the results Katie and Winston record are accurate. Doubts are raised about the accuracy of Hari and Rebecca's results as Rebecca's report (account 3) suggests that they may have used a different number of books to support the tubes and consequently this would not be a 'fair test'. Further doubts are cast on Hari and Rebecca's conclusions as they have the same results but have drawn different conclusions about down which tube the marble would roll faster. The activity was designed so that children could discuss two issues: one, down which tube they thought the marble would roll down faster and two, why Hari and Rebecca had made different conclusions to each other. Evidence the children could use was provided in the accounts of the methods used for the investigation and also the results recorded.

At the end of the activity the children were curious as to what had happened to Rebecca and Hari's investigation and so discussions took place to satisfy their curiosity rather than to address any ethical issues arising from the discussions.

5.7 What sample of schools should be used in the research?

As the purpose of the pilot phase was to test out research techniques and not to find the range of children's abilities, the type of schools used was not crucial to this part of the study. Therefore, the choice of pilot study schools was based on the consideration of ease of access to primary school classrooms. As discussed in section 5.5.1 the pilot study involved four different schools.

The pilot phase confirmed that gaining entry to schools was facilitated by the researcher's experience as a science teacher and lecturer in science education. Science is a subject in which many primary teachers lack confidence in their subject knowledge (Watt and Simon 1999) and class teachers could have been reluctant to allow an unqualified person to work with their pupils. The Headteachers were informed that the researcher was a qualified science teacher with twenty years' teaching experience, so that they could be confident that relevant and correct teaching materials would be used.

Working in higher education meant the researcher had contacts in a wide range of schools in different Local Education Authorities. Each school was approached in the first instance by a letter to the Headteacher. This letter gave brief details of the study and named the person who was the contact and, in all cases the Headteacher gave permission for the school to be involved in the research. However, in one school, the timetable was so inflexible it was not possible to use activities in the classroom that were outside the scheme of work followed by Year 6 classes and so the school was not used for further research. This lack of flexibility illustrates how teachers may feel constrained by the National Curriculum, as the PACE project (Pollard et al. 2000), discussed in chapter 4, identifies.

If we are to ensure that argumentation is introduced into primary school classrooms we must make it clear how decision-making activities will help meet specific requirements of the National Curriculum. As a consequence of this finding in the pilot phase, it was made clear to the Headteachers of the main study schools for the main study, that the research would involve activities that might not fit into the class's current science programme.

In the pilot study the teachers had chosen the children most likely to cooperate but in the main study the sample was 'purposive' (Miles and Huberman 1994; Baxter et al. 1996) as the research aimed to study children with a range of abilities. However, it was impossible to work with the whole ability range as, for example, children who could not read would not be able to take part in the activities as most of the given evidence was written. Data on the children's levels of abilities, made available by the schools, is given in Appendix 8.

The main study schools were selected to provide this range and to produce the most valuable data (Denscombe 2003). As Edwards and Westgate (1994) suggest that the social group and cultural groups of children affect their ability to make their ideas verbally explicit, the schools chosen involved children representing a range of ethnic and cultural origins. The groups included girls and boys, children from a range of ethnic origins and from different social and cultural groups. A summary of the schools and groups used in the main study is given in Table 5.4 and further details are given below.

Table 5.4 The schools, classes and groups used in the main study

School	Class name	Group
St Anne's Group 1	6O	Luke, Naveed, Osei and Sheerah.
St Anne's Group 2	6L	Alicia, Daniel, Heidi and Junior.
Castle Hill	Yr 6 Scholars	Alex, Cicely, Joanne and Simon.
Woodstreet Junior Group 1	6M	Amy, Che, Jillese and Patrick.
Woodstreet Junior Group 2	6D	Chantal, Elijah, Jason and Sharon.

As in the pilot study, the schools were contacted by a letter sent to the Headteacher. The letter gave brief details of the study and the name of the person who had recommended the school to the researcher. Again, the letter emphasised the professional qualifications and teaching experience of the researcher, so the Headteacher would know that the researcher was familiar with the life of a school (Strauss and Corbin 1998). The letter did not specify precisely what the research was about because, as Delamont (1992) points out, this could 'colour the response' and the class teachers may have informed the children that the activities concerned the way evidence was used. The three schools were very different from each other as the following accounts illustrate:

St Anne's Primary School

St Anne's is an LEA primary school with a nursery class and so the children can attend from aged three to eleven years old. The school's prospectus describes the school as a community school that enjoys a mixture of people from a wide range of abilities, social and ethnic groups. The school is an above average in size, having 355 pupils. The area immediately surrounding the school is mainly residential, with some businesses and light industry located nearby. Many of the surrounding houses are privately owned but the school does cater for children from a local housing estate. The social and economic backgrounds of the children vary greatly and whilst many of the parents are employed other children come from families where the parents are unemployed. Thirty per cent of pupils are eligible for free school meals and this is above the national average for schools of a similar type (Ofsted Report 1997). The research involved two groups of four pupils from this school, one group from Class 6O and the other from Class 6L.

Castle Hill School

Castle Hill School is an independent preparatory school set in seventeen acres of woodland and fields with a pre-preparatory school (ages two to seven years old) on the same site. The main school (ages seven to thirteen years old) teaches towards a 'Common Entrance' curriculum and scholarship examinations but the children also sit the Key Stage 2 SATs. The science department has four spacious and well-equipped laboratories and four specialist science teachers. The prospectus states that: Pupils are encouraged to work together in co-operative, problem-solving teams, whereby each teacher is a catalyst rather than an instructor. One of the science department's specific aims is to foster children's thinking through discussion in science. There was only one group from this school as the Head of Department considered only pupils in the highest ability group, the 'Scholars' class, could be taken out of lessons for the research activities.

Woodstreet Junior School

Woodstreet Junior School is an LEA school that caters for pupils in Years 3-6, aged seven to eleven years old. The infant school is nearby but has a separate Headteacher and staff. The school is in an urban area and the pupils and staff are represented by a range of racial groups. This diversity of racial origins is a significant feature of the display on the walls in the school entrance. Over 60% of the children are eligible for free school meals and 5.6% of pupils have special educational needs (average for the LEA was 1.7%). The school's prospectus outlines the standards of behaviour expected of the children and adults entering the school. The first point addressed to the adults is that: Adults are not permitted to display themselves in a verbally or physically aggressive manner in front of the children. This statement gives some indication of the challenges faced by the school. There are 22 support assistants comprising both learning support assistants and classroom assistants. The research involved two groups from this school, one group from Class 6D and the other from Class 6M.

5.8 What type of role should the researcher adopt?

The dual role of researcher/teacher adopted for the pilot study had proved to be effective as the children had managed their discussions autonomously (i.e. without a 'teacher' input) but they asked questions, for example, the meanings of words, of the 'teacher' when necessary. The same procedures were used for the main study.

Although this scenario meant that there was 'teacher' directing them towards a conclusion, the researcher adopted the role of teacher when giving instructions and sometimes acting as a source of information. The children were told that they could ask the researcher any questions about the work they were doing, in the same way as they would ask their own class teacher. It was anticipated that the children might ask about the meanings of some words or how to pronounce some words (for example, 'wood preservatives' in the Bats). The researcher also had to act as a teacher when giving the children directions about where to sit and when to start. The other role taken by the researcher involved the operation of the tape recorder and video camera and the taking of notes. The two roles did not appear to present any conflict for the children and they behaved in a relaxed and co-operative manner.

One point of difficulty arose when the children were heard discussing ideas that indicated they had misconceptions of a scientific nature. As the children knew the researcher was a science teacher, failure to address these issues could reinforce these incorrect ideas. It was decided that the misconceptions would be addressed after the recording had finished. As the Gerbils involved a choice that could easily occur in the lives of these children and the choice is crucial to the well-being of a pet gerbil, after the children had finished the activity it was always explained that Home 3 was the best choice. The experience of working with children in the field was much the same as Holmes who reports that:

> most children accept my explanation of the project and my presence, and most never gave it any thought after that.
>
> (Holmes 1998: 16)

5.9 What is the most effective recording (video and/or audio) technique?

Not all points in a discussion are made through speech as some are made through gestures and pointing at objects (Driver et al. 2000), so all conversations between the groups of children were both video and audio-taped. The videotape helps capture an authentic image of the event and also provides data that can be analysed over and over again (Schratz 1993). Video recording can also help overcome difficulties in identifying the speaker especially when dealing with multi-party talk as opposed to a two-person interview (Samra-Fredericks 1998).

The pilot study had provided the opportunity to try out different recording techniques to decide on the eventual method of recording (video and/or audio) and the place of recording (in or outside the children's own classroom). The findings indicated that although recording in the classroom might capture a more 'real-life' situation, distinguishing each child's speech with the recording equipment available was impossible above the noise of the class. After the first attempt at recording inside the classroom, all subsequent recordings took place outside the classroom away from the rest of the class.

Using audio-tape recording and a video camera proved to be essential for capturing as much information as possible. The audiotape was used to produce the transcripts but the videotapes provided clarification about which children were speaking and to whom they were speaking. The videotape also provided information on what the children were referring to when they said 'this one' or 'that one'. This identification was particularly relevant when the children referred to a cup or gerbil home. Gestures and facial expressions were recorded on the videotapes, which helped in the final analysis of the data. Consequently all discussions were videotaped and audio taped in the main study.

5.10 What is the appropriate number of children to have in a group?

In the classroom, children can work in groups of a variety of sizes. Alexopulou and Driver (1996), working with older children (14 to 15 years old), found that groups of four functioned better in terms of the group discussion process because they had a wider range of opinions than a pair. Jarvis (1993) also suggests four is the optimum number for a group as she found that groups of five or six often broke down into pairs and threes. In the pilot study, different sample sizes of group were explored in the Bats to test the most appropriate group size for children aged ten to eleven years old. The activity was carried out with children in groups of four, in pairs and as individuals. The following conclusions about optimum group size were made.

5.10.1 Working as an individual

The individual child provided very poor data as the following example indicates. Steven's plan, shown below, demonstrates that although he changed his ideas between the first and second plans of action, it was not possible to track all the pieces of evidence he had used to arrive at these changes. Therefore his thinking is not 'made visible' (Linn 2000). Steven had to choose what to do about bats in the roof of a library and to make a plan of action.

Plan 1:

> *I think they should move the books away for a while, cover up the floor with plastic sheets and call in the RSPCA.*[1]

He was then provided with the *BAT FACT?* Cards that he read by himself but he did not discuss his ideas with anyone else. Having read the information he was then given the opportunity to change his ideas and write a new plan. Plan 2 shows that he has responded to the information that explained why bats do not use a roost all year round as, in winter, they hibernate in caves, old mines or hollow trees.

Plan 2:

> *I think they should go over the roof and cover up the holes in the cieling (sic) and when the bats go and hibernate they should go up and cover the hole/holes in which they came through. Then take the temporary measures down.*[2]

However, as he did not talk to anyone as he read the cards it is not possible to see which other pieces of information he has considered and rejected in coming to his final plan. Steven completed the task very quickly, and it is impossible to tell how much of the evidence was reviewed. The pilot study demonstrated that an individual child appeared not to be as interested in the task as when another child was involved.

Children working as individuals, had no one to challenge or to be challenged by, thus there was no demand for explanations and so little of their thinking was made visible. Making thinking visible is crucial to identifying how thinking impacts on decision-making. Fisher (1998) explains how speech is an important vehicle to demonstrate people's thinking, just as the drawing is important to show the architect's thinking about

[1] This is a copy Steven's 1st written plan
[2] This is a copy Steven's 2nd written plan

a design for a building or a model to show a sculptor's plan for a statue. When talking amongst themselves children do think aloud but their discussion may be limited by verbal skills, peer-group pressure and self-esteem (Bradley 1996). So, making thinking visible is, as Linn (2000) suggests, far more easily advocated than accomplished.

5.10.2 Working in pairs

When working in pairs, the children did discuss the evidence as extract 2 shows. Here, Linden and Mary are discussing their plans for dealing with the bats in the library. Mary's plan was to bring in the RSPCA to capture the bats and take them out of the library or to tranquillise the bats and move them to another habitat. Linden had suggested building a new habitat for the bats and getting someone from pest control to evacuate the bats. The extract shows Mary and Linden have similar plans and so they are not presented with many opportunities to challenge each other. Therefore, there is no real necessity to justify a decision. Linden does not respond to Mary's idea of using tranquillisers and she does not agree to Linden's suggestion until he asks for a response by asking Mary whether she agrees with him ('Yeah?' is formed as a question; see line 11).

Extract 2

4. **Mary**: The RSPCA can take them away.
5. **Linden**: The RSPCA can take them away or have …
6. **Mary**: (interrupts) We could use tranquillisers because they don't harm them do they?
7. **Linden**: Have the RSPCA …
8. **Mary**: (interrupts) And they can be vicious, bats.
9. **Linden**: Have the RSPCA take them away and take them to a new habitat.
10. **Mary**: We did tranquillisers because bats bite.
11. **Linden**: Yes, have the RSPCA take them away without harming them to new habitats. Yeah?
12. **Mary**: Right.

Working in pairs means that discussion might be limited as few challenges may be made to each other's ideas and suggestions. To stimulate more debate, a wider number of views are required.

5.10.3 Working in small groups

The value of children working with peers is that the presence of other children 'provides a natural context for elaborating one's own reasoning' (Teasley and Arbor 1993). The data indicated that using groups of four children provided the most information about how children use the evidence and how it influenced their decisions. Having a group of four children ensured that the children had opportunities to argue and discuss as they have different points of view, and as Jarvis (1993) found, a group of four is small enough so that all the members can contribute to the discussion. Groups of four also allowed girls and boys to be equally represented and mixed groups are important because, as Jarvis (1993) points out, all-girl groups may want to seek agreement rather than challenge each other's ideas.

Groups of six were not explored as groups this big would limit the possibility for all children participating, especially when there was no teacher involvement encouraging all the children to take part. As a result of these findings: groups of four children, two girls and two boys, were used in all but one case, in the main study. This group had three girls and one boy, due to the absence of one the boys for the first activity. As the research concerned how the groups use evidence together, it was decided to keep the composition of the group the same for the rest of the activities.

5.11 Comparing the individual's performance in using evidence

In order to find out if the children, as individuals, used evidence in different ways from when working in their groups, they were interviewed on their own after each activity. The children were asked about which choice they had made and if they did not offer any justification for their choice, they were then asked why they had made such a decision. If they did not explain why other choices were rejected, they were asked to do so. The data are used to see if children demonstrate the same skills in reasoning and using evidence when working in a group and when working on their own. If children demonstrate different skills in group work then there are important considerations to made about the composition of the groups. Teachers need to know if the actions of children in the group affect the way an individual reasons and uses evidence and if so, what composition stimulates the exploration of evidence, encourages children to support their claims and ensures that a number of alternatives are explored. These ideas are explored in depth in chapter 8 when the roles children adopt in the group activities are discussed. Full details of the questions posed to the children in the interviews are given in the next chapter as these questions help explain how the data can be analysed to show children's individual performances.

5.12 Ethical considerations

The pilot study raised some ethical considerations for the researcher working with children in schools. Working with children presents a researcher with considerations not usually associated with adults, particularly when gaining informed consent. Informed consent requires giving the subjects information about the research so that they can choose whether to take part or not. Two main concerns were identified in the pilot phase. First, it is difficult for children to withdraw consent when a teacher has asked them to take part in an activity so every time the children took part in an activity they were asked (outside the teacher's view) if they really did want to take part in the activity. It was very easy to detect the children's enthusiasm to take part in something different and be outside the classroom and no child withdrew from the research. The decision to seek parental consent was left to the school. Permission was gained from the children to record their conversations and they were told that their teacher would not listen to the tapes.

Second, to inform them about purpose of the research was not possible, as the researcher did not want them to know what was being studied in their discussions. Denscombe (2003) suggests that it would be acceptable to give the children only part of the information, as long as any use of materials would not cause anyone to suffer as a result and that they do not disclose the identities of those involved. None of the materials produced in this study could have caused any problems for an individual or group as any ethical issues raised by the activities were addressed later with the children. To avoid disclosure of identities, pseudonyms are used for the schools and only the first names of the children are used in this thesis. The children were informed that when the study was reported fictitious names would be given to their school and they found this amusing and often suggested new names for their school.

Conclusion

The pilot study was essential in finalising the research methods adopted in this study and indicated which activities were suitable and where changes were necessary. The pilot study showed that recording children talking in decision-making activities does provide data that can be analysed to show how children reason and use evidence to justify decisions. Thus the research methods developed were suitable to answer the questions posed in this research.

Summary

In this chapter, the development of the research methods has been set out and the approach adopted in this research has been justified. Details of the pilot study have been included to show how decisions were made about the activities used in the main study and also about the techniques to use in collecting the data. The four activities used in the main study have been described and information about the main study schools has been included to show the type of schools involved in the research. Ethical concerns about working with children have been considered and how these concerns were addressed has been explained. The development of the analytical framework and the design of the coding schemes and techniques used to analyse the data is the subject of the next chapter.

Chapter 6 The development of the analysis techniques

6.0 Introduction

The previous chapter focused on the design of the research methods used in this study and explained the reasoning behind the way the data were collected. The focus of this chapter is to describe the development of the techniques used to analyse this data. First, details of how the data were prepared for analysis are given and then the framework for the analysis is introduced.

The chapter begins with an explanation of how the transcripts were constructed from the recorded data, taking into account children's verbal and non-verbal behaviour. The aim of the analysis was to identify the ways children make use of evidence and their different approaches to argumentation. The analytical framework was developed using Mitchell's (2001) parameters of good argument. Details of these parameters, selected to identify good argumentation in children, are given and then the coding schemes designed for each of these parameters are introduced. Initial analysis of the pilot study data highlighted the need for a variety of coding schemes and four different coding schemes were eventually used. Extracts from the transcripts are included to show how the four coding schemes were developed from the analysis of the pilot study data.

6.1 Preparation of the transcripts

This section explains how the transcripts were prepared from the recorded data and the field notes taken by the researcher. In the pilot study, the transcripts were prepared initially by listening to the audiotape and then were transcribed by the researcher using speech recognition software. Transcribing the tapes in this way was a very time-consuming process but because it involved close and repeated listenings, it facilitated familiarisation with the data more effectively than if someone else had transcribed the tapes.

It was important that each speaker was identified accurately and yet the voices of the children at this age can sound remarkably alike. Field notes and video recordings provided further clarification of which child was talking to whom. It was also important that the choices considered by the children could be identified, for example, which cup they were discussing or which gerbil home they were looking at. The videotape facilitated the identification of what children were referring to when they said 'I think this one'; as the video recording showed which cup or which picture they were holding. This procedure was important in order that specific pieces of evidence used by the children could be identified.

Sanger (1996) suggests transcripts under-represent the communication taking place and that a direct transcript of the spoken word misses out some important aspects of a discussion. For example, when children are not saying anything they can still be contributing to the discussion by nodding their heads in agreement or shaking their heads in disagreement. Likewise, they could be gazing around the room and not taking part in the discussion. Consequently the transcripts are embellished to indicate what children are doing as well as what they are saying and contextual information added to the transcripts is presented in brackets. Preparing the pilot study transcripts to include the spoken word of the discussion and also information from the notes and video recordings provided useful data that could be analysed and so the same procedure was adopted for the main study.

To preserve anonymity for the schools and children involved in the study the transcripts give just the first name of each child and a pseudonym for each school. The transcripts are punctuated for the sake of intelligibility but where extracts are provided in this chapter they have been quoted verbatim.

There are 21 transcripts from the pilot study (from a range of activities) and 20 transcripts from the main study, one for each of the four activities from five different groups of children. Preliminary analysis took place as the transcripts were prepared and this indicated that several strands of analysis would be needed to gain an in-depth description and understanding of children's engagement in scientific argumentation. Eventually four different analytical approaches were used and the next section explains how these strands were identified.

6.2 The analytical framework

The key aim of the analysis of the research data is to gain insight into how children use evidence when engaging in decision-making activities. In the previous chapter, the questions that framed the enquiry of this research project were given in section 5.3. Essentially, the research aimed to find out if children appreciate how the evidence can support one claim better than another and also what might be wrong or inconclusive about the evidence they are examining. The process of examining evidence that can support competing claims engages children in argumentation and therefore, an evaluation of children's use of evidence means that the quality of their argumentation can be studied.

To assess the quality of argumentation it is important to identify criteria by which such judgements can be made. Mitchell (2001), in her essay 'What is this thing called argument?' discusses the need to have a clear view of what argumentation is so we can clarify what the requirements are for good argumentation. She provides a list of parameters that she suggests we should be looking for in argument. For the purposes of the research reported in this thesis, certain criteria have been selected from Mitchell's list. These criteria are ones that we could expect children, aged ten to eleven years old, to demonstrate in the research activities in which they took part, i.e. the children should:

1. discuss most or all of the evidence made available;
2. provide claims supported by evidence;
3. test alternative choices and consider both positive and negative issues of the possible options;
4. engage in sustained dialogue by making claims, reviewing evidence and discussing arguments as an iterative process.

These four criteria form the basis for the different levels of analysis used in this research and schemes were devised to analyse the transcripts in relation to each of these levels. Table 6.1 summarises the four different aspects of the analysis and includes a brief description of each aspect. The TAP analysis, referred to in Table 6.1 overleaf, stands for Toulmin's Argument Pattern (Toulmin1958). As explained previously in section 3.4.1, Toulmin identified a pattern that can be used to analyse arguments. More details of this strand of the analysis are given below.

Answers to the questions given in Table 6.1 enable some of the research questions to be addressed directly, for example, 'Do children explore all the evidence?'. Answers to some other questions, such as, 'Is there any difference between the ways children use evidence presented in different formats?' will draw on different strands of the analysis. Details of how each coding scheme helped answer the research questions are given in chapter 7.

Table 6.1 The four aspects of the analytical framework

Aspect of the analysis	Coding schemes used
Use of evidence	
1. Do the children discuss most or all of the evidence made available?	**'E' number codes:** The source of the evidence is identified
2. Are claims supported by evidence?	**TAP analysis:** Where claims are supported by reference to evidence **Model Arguments:** Features of the arguments for the groups' decisions are identified **Interviews** To identify whether children justify their claims in the individual interviews
3. Do the children test alternative choices and consider both positive and negative issues of the possible options?	**Alternative choices:** The choices considered by the whole group in each discussion are identified
Pattern of Argumentation	
4. Do the children engage in sustained dialogue by making claims, reviewing evidence and discussing arguments as an iterative process?	**Discussion Maps:** The pattern of the whole discussion is identified **Levels of argumentation:** Different categories of increasing sophistication in argumentation

The techniques for the four aspects of the analysis were developed gradually as the analysis of the pilot study data revealed some of the limitations of each scheme. The following sections describe how the analytical schemes developed in the pilot study informed the design of the schemes that were eventually adopted for the main study. Extracts from the transcripts are given to illustrate how the analysis technique was applied and, where relevant, to identify the shortcomings of the technique.

6.3 The coding schemes developed during the pilot phase

For a taxonomy to be valuable in interpreting data, the categories must be precise enough for different coders to produce the same results, otherwise there can be no assurance of their reliability. As Silverman (2000) explains, categories should be clear and unambiguous and repeated analysis should result in the same categories being assigned, whether by different people or the same person on different occasions. In addition, the categories need to incorporate all behaviours consistently observed or the analysis will be incomplete. However, categories that are based on behaviour that is observed just once in a set of data may be unhelpful as they may give undue emphasis to this behaviour.

The initial attempt at analysing the transcripts focused on how children used the evidence in their discussions and a taxonomy of children's responses to evidence was developed. However, this taxonomy identified *whether* children used evidence rather than *how* they used it in forming opinions or making decisions. Although this taxonomy was not used in the final analysis, a description is included below in order that the development of the final coding techniques can be understood. Essentially, the initial taxonomy clarified further what the final coding schemes needed to reveal. It indicated that they needed to be more sophisticated to facilitate a deeper analysis of the data about how the children used evidence in their discussions.

6.3.1 The initial taxonomy

The initial taxonomy was developed from the reading of six of the transcripts from the pilot study. Transcripts from the Shoes, the Bats and the Cups activities were read and incidents where the children used evidence were noted. These behaviours included where the evidence was used to support and defend a choice, where evidence was cited that had not been given to the group, where evidence appeared to be ignored and finally where evidence had been invented to support a claim. These groupings led to the taxonomy of children's responses to evidence shown in Table 6.2. Each of these categories will now be explained along with extracts from the transcripts to show how the initial taxonomy was created. The taxonomy, although helpful in beginning the process of data reduction by simplifying and transforming the data (Miles and Huberman 1994), had some important limitations. The limitations of each category are then explored to show how the final coding schemes shown in Table 6.1 were developed.

Table 6.2 Children's response to evidence

Category	Response to Evidence
1	Uses the evidence provided to make a decision.
2	Discusses the evidence but does not use it to make a decision.
3	Uses own personal experiences as evidence to support a claim.
4	Ignores the existence of evidence.
5	Invents evidence to support view.

Category 1 of this pilot taxonomy led to the development of the TAP analysis, category 2 and 3 to the development of the 'E numbers' coding scheme. However, categories 4 and 5 were not found to be useful for analysing how children used evidence as no further examples of each type were found in any other transcripts and consequently the description of these last two categories is brief.

The five categories listed in Table 6.2 are now discussed and extracts from the transcripts are included to illustrate the five different ways children responded to evidence in the pilot study. In the extracts from the transcripts that follow, comments from other children in the group are included only if it helps to make sense of the conversations. Some of the extracts are taken from the children's discussions and some are taken from interviews with the children about their choices. Comments and questions posed by the researcher are indicated by the initials, **J.F.M.**

6.3.2 Using the evidence provided to make decisions

The first example illustrates where evidence has influenced the children when making a decision. The following account shows how Rick read a piece of evidence that caused him to change his mind and subsequently develop a new idea. The category assigned to this extract is category 1 (see Table 6.2) as it shows when the evidence prompts a child to alter a decision.

This example is taken from the Bats where the children were presented with the problem about bats being in the roof of the library. The children first made an individual plan about what to do about the bats and Rick wrote the following:

> They should go into the loft and take them out and put them in a cage. Then they should take them somewhere that they will be looked after (sic) [1].

After the children had read the *BAT FACT?* Cards they were given the opportunity to construct a new plan. The evidence given in the cards indicated that you cannot just remove bats from their roosts as it is against the law.

When Kristy announced that they had finished the children were asked if they had changed their original plans. Kristy, answering for the whole group, said they had not changed their ideas. However, Rick appeared to be dissatisfied with this outcome and continued the discussion as shown in extract 1, line 185 where he referred back to one of the *BAT FACT?* Cards he had earlier read out. The transcript shows that although the children had not fully explored the implications of this piece of evidence, Rick was aware of the shortcomings of their plan to move the bats. This is shown when he repeated the fact that bats do not stay in a roost all year round, (line 185). He had read the card out earlier but he did not begin to 'make his thinking visible' (Linn 2000) about the implications of this evidence until this stage.

---

[1] This is a copy of Rick's written plan

Extract 1

185. **Rick**: one of them says, it says here in winter, 'Once you've got bats in your house they will always be there' - it's false
186. **Tom:** (reading) 'Bats do not use a roost all year round. In winter they hibernate in old mines and hollow trees'
187. **Kristy:** so they would have moved in the winter?
188. **J.F.M:** so can I just come back to Rick? He said something about the winter. What were you saying Rick?
189. **Rick:** I was saying you could have left it until the winter
190. **J.F.M**: and then what would have happened?
191. **Rick**: they would go away to hibernate

Rick had interpreted the evidence correctly and had recognised that they should delay moving the bats until winter. His suggestion that they wait until winter, shown in extract 2, demonstrates Rick's understanding of the evidence that bats cannot be disturbed when they are roosting.

Extract 2

199. **Rick:** No, that's what I was saying about winter, if they are roosting we can't take them out until it is winter. In winter they hibernate and they will be out and we can do something. Sort out wherever they got in.

His response to the evidence can be seen by the change from his first plan (moving the bats out of the library and putting them in a cage) because he realised that the bats cannot be removed while they are roosting. His new idea was that something could be done to prevent the bats coming back to the library once they have left to hibernate elsewhere in the winter. This change came about as a direct response to the evidence.

This category indicated that the final coding scheme needed to identify where evidence was used to support a claim and led to the development of the TAP analysis as will now be explained.

6.3.3 Using evidence to support and justify decisions - the TAP coding scheme

To analyse whether children used the evidence to support and justify their choice, arguments were identified using a framework known as 'Toulmin's Argument Pattern' or TAP (Toulmin 1958). A TAP consists, in its simplest form, of a *claim* supported by an appeal to *data*. Identifying an 'appeal to data' will indicate that a claim has been justified in some way, usually by a reference to evidence. The claim may be supported by a *warrant* that explains the link between the claim being made and the 'data'. Further support can come from *backings* that lend authority to the warrant.

In examining whether the children used evidence to justify their claim, the individual arguments, usually put forward by one child, are identified. Examples from the transcripts will now be given to illustrate how the coding has been applied to the transcript:

Junior's *claim* is that he does not like Home 2 and the *data* he appeals to in order to justify his claim is that the holes are too small. The implicit *warrant* is that a big gerbil would, presumably, get stuck in narrow cylinders. However, Junior does not give the reason why small holes make Home 2 an unsuitable choice as he is interrupted.

Extract 3

35. **Junior:** The thing I don't like about it (Home 2) is that the holes (in the cylinders) are too small, 'cos if it's a big gerbil ...

Further examination of the transcript shows that Alicia supports Junior's argument and she does provide the warrant for this argument (see extract 4 below).

Extract 4

54. **Alicia**: Yes, and if it's too big, it might get stuck.

This incident indicated that the transcripts needed to be examined to see if arguments were constructed by one child or by two or more children. Co-construction of arguments illustrates that the group is working together in building arguments for and against the various choices.

On examining the transcripts for TAPs it became clear that the children make claims based on evidence in two different ways. The most common form that occurred in the transcripts was when a claim was made and the evidence was then cited to support this claim. For example, in the Gerbils, Sheerah claimed that Home 2 is better. Her claim was based on the evidence that you can extend Home 2.

Extract 5

20. **Sheerah**: I think that's (Home 2) better because you can extend it.

She read the evidence, made her claim and appealed to this evidence to support her claim. Thus the form is:

Claim *because* Data

The alternative form represented in the children's discussions was when the data comes prior to the claim. In the following example, one child provided the data that prompted a second child to make a claim.

Extract 6

64. **Che**: By adding more you can make it bigger (Home 2)

66. **Patrick**: So it's good, I'd go for this one (Home 2)

Che provided evidence that Home 2 can be extended and Patrick responded by making a claim that Home 2 was good and that he would choose this home as a consequence of the evidence cited by Che. Thus the form for this pattern is:

Data *so* Claim

Thus the same piece of data, that Home 2 can be extended, was used in both forms of TAP to support the claim that Home 2 was a good choice.

In the initial stages of coding the transcripts reliability checks were taken and another person[2] coded some of the transcripts in addition to the researcher. In each case, discussion took place until there was inter-coder agreement (Silverman 2000) for the TAP codes. Further reliability checks took place when the transcripts were analysed for

[2] My PhD supervisor

a second time by the researcher and consistency in the allocation of TAP codes was established.

As explained below, the next two examples show that a coding scheme needed to be developed to track the use of particular pieces of evidence in the discussion.

6.3.4 Discussing evidence but not using it to make a decision

The transcripts show that some children discussed evidence that did not lead them to make claims or to come to a decision; this type of response forms the second category in the initial taxonomy.

The following example has also been taken from the Bats but from another group of children who followed the same procedure as Rick's group, as discussed above. The following extract is taken from an episode where the children had read the evidence and were reviewing their joint plan that involved calling in an exterminator to kill the bats.

Extract 7

132. **Connor**: We can't call the exterminator 'cos they've done nothing wrong.
133. **Kelly**: They are not bad.
134. **Connor**: Don't call the exterminator.
135. **Kelly**: They are not blind, they can see.
136. **Sharma:** It's against the law to keep one, isn't it?

Kelly's contribution is a reference to evidence about the sight of bats (line 135), which was correct, but irrelevant to the choices they have to make (Whether bats can see or not is irrelevant to the solution of what to do with the bats.). Kelly was responding to the evidence but she was unable to select the facts that were relevant to the task and therefore, unlike Rick, does not use the evidence to come to a decision.

The category does not distinguish between responses where evidence was just reviewed and where evidence was used by the children to justify a change of mind or a decision made. Sometimes the evidence was read out but was not used constructively in the debate. Thus it became clear that the individual pieces of evidence discussed needed to be identified so it can be shown where evidence was reviewed and also where it was used to support arguments. However, the evidence the children used to support their claims was not only drawn from the information they had been given in the activities. The children also drew on other evidence, such as their own personal experiences.

This category from the initial taxonomy indicated that a coding scheme was required that could identify the individual pieces of evidence in order that the source of evidence to be traced as well.

6.3.5 Using own personal experiences as evidence

The third category of the taxonomy is where children use evidence not just from the information given to them but also from their own and other's experiences to support claims and justify arguments. The following example is taken from the Cups where the children have to choose one cup to take on a picnic. Sean was concerned about the safety of the glass and the thin plastic cup. He is worried that the glass cup would break and the thin plastic cup would tear.

Extract 8

65. **Sean**: The glass, it could smash. ... and little kids if they bite it (*the thick plastic cup*), it won't go through. But the thin plastic, ... my little brother once bit one and it made a big cut down the side of it and the glass one could do their throat in.

Later in the discussion Sean's story about his little brother was used by others in the group as evidence. Two girls used the information that the thin plastic cup 'gets ripped' as a reason for rejecting this cup for use on the picnic, yet the activity had not explored this property in any of the cups.

The source of the evidence, either from the information given in the activity or from personal experience is an important feature of how children use evidence that had not been clearly distinguished by the original taxonomy. Categories 2 and 3 indicated that a coding scheme was required to identify individual pieces of evidence and the development of the 'E number' codes facilitated this analysis as will now be explained.

6.3.6 The evidence used by each group - the 'E number' codes

The children were provided with evidence in the form of written evidence (and pictures in the Gerbils) but they drew on other sources such as personal experiences and the comments of other people. The evidence was identified using the codes E1 and E2; E1 is evidence taken from the written text or the pictures of the homes and E2 is evidence that the children cited which was not provided in the information made available to them. The identification of the E1 codes was straightforward as it would be easily seen if the information was taken from the written text or the pictures of the homes. E2 evidence may have been a direct experience of the child or have included reference to the experience of someone else: for example, a child might describe something that happened to someone in his or her family. Examples of the two types of evidence are shown in Table 6.3.

Table 6.3 Codes for source of evidence

E1	**Evidence from the information sheets** **Alicia:** I think I choose this one (home 3). **Heidi:** But it hasn't got any exercise wheel (this is shown in a picture and in the text). **Junior:** True, yes, but this one (Home 1) ... **Heidi:** *(interrupts)* In this one (Home 1) it has an exercise {wheel}.
E2	**Evidence from personal experience** **Heidi:** It's (Home 1) plastic (E1) … It can't break. I used to have a plastic cage and my hamster didn't die even when the whole home dropped (E2).

Evidence in the E1 category was subdivided into specific pieces of evidence for each of the activities. For example, each piece of information on the *Homes for Gerbils* was coded separately. How these codes for E1 evidence were allocated for each activity is shown in Appendix 9. Having separate codes for the evidence made it possible to quantify how many pieces of evidence each group used. The frequency of use of the evidence for each category can then be calculated. This demonstrates whether children rely on one source of evidence more than another. For example, they may draw more on their personal experiences than the information supplied to them. This analysis also shows whether the children use evidence differently when it is presented in different formats.

Coding the evidence used in this way meant that it was possible to identify evidence given on the sheets that was *not* used by the children. Many pieces of evidence were ignored and although this may have been because of lack of knowledge, it still indicated *whether* the available evidence was used in the decision-making process.

The next two categories of the initial taxonomy were not developed further after the pilot study as no other examples of these types were found in subsequent data. Although category 5, 'Invents evidence to support view', was thereafter omitted due to the infrequent instances in this research, primary school teachers confirm in personal communications that they have also observed children in their classes making up data to support a conclusion they think is acceptable. So it may be needed as a category in further research when analysing how children use evidence. The following sections refer to instances of these last two categories.

6.3.7 Ignoring the existence of evidence

This fourth category shows that some children when confronted with evidence appear to ignore it and their explanations do not take the evidence into account. This is illustrated in the following example. The extract is from an interview with Badri following the friction investigation (Shoes) in the pilot study. The children had tested different shoes to see which exerted the greatest friction. The results had shown that Badri's plimsoll had exerted the greatest friction. The children were all interviewed separately a week later in order to see what conclusions they had drawn from their data. The question in this extract was designed to see if the children would use the evidence to justify their conclusion.

Extract 9

313. **J.F.M**: What if someone said 'You must have made a mistake - the plimsoll can't have more friction than the trainer?

314. **Badri**: We tried it again and again ... we done it first and then none of them moved and then we done it up... and at about 30cm and they ... em ... then two started to move and then after that the ... we done it even higher to see... the other shoes moved a bit and then after that... the it.. we kept it there for about ½ minute and after that we put it up and it started to move down.

Badri appears to be unable to refer to the evidence that they had recorded during the lesson. She just recounts what they did rather than what her results actually tell her about the friction exerted by the shoes.

6.3.8 Inventing evidence to support a view

As its title indicates this final category shows that children make up evidence they think will support a claim even though the evidence cannot be substantiated. This example is taken from the Shoes. The chart Tom had recorded in his science book had been completed incorrectly and when questioned about this, Tom acknowledged that the data showed that all the shoes had the same friction. Yet he had written in his book that "The plimsol has the Greatest friction (*sic*)". To see if Tom could explain how he knew the plimsoll exerted the greatest friction he was asked how he had drawn this conclusion. He explained that while he was drawing the chart in his book, they had left the shoes on the slope and he observed that the plimsoll had stayed at the top while the other shoes moved. Extract 10 shows how Tom justifies his choice.

Extract 10

276. **Tom**: We left them on the slope. Three of them had moved. The plimsoll stayed still.
277. **J.F.M**: How do you know they had moved?
278. **Tom**: Because we drew a line across the top of the board. We looked at it and the ... shoes had moved a millimetre away from the line.
279. **J.F.M**: Who measured this?
280. **Tom**: We all did. One of us spotted it. Kristy spotted it and so we looked ... we all looked at the shoes and marked them off.
281. **J.F.M**: How far did the shoes move?
282. **Tom**: About two or three.

Observations and the videotape indicated that this had not, in fact, taken place and Tom appears to be making up evidence. His version of events does support the same result; i.e. the plimsoll exerted the greatest friction, but his account of how they recorded the data is fabricated. Children might make up evidence in this way if they think they have the correct answer but cannot provide any evidence to support their claims. This suggests that they have a confused respect for evidence. Although they believe evidence is important for backing up a claim, they are still prepared to fabricate evidence if they do not think they have sufficient evidence to be convincing.

The research data from the pilot study showed that children can and do use evidence in coming to decisions; some children respond to the evidence and change their decision, some use the evidence to try and change other children's decisions while others select the evidence that supports their decision. However, it became clear that further analysis techniques were needed to address all the criteria identified in section 6.2. For example, the analysis techniques used in the pilot study had not shown whether children considered a range of options or whether they engaged in a sustained dialogue. Consequently new schemes were developed to address these issues. The following account explains how these schemes facilitated further analysis of the data.

6.4 Identifying the number of alternative choices considered

It was established in section 6.2, that one way to analyse how children are using evidence is to see whether they test alternative choices and consider both positive and negative aspects of the possible options. In two of the activities, the Gerbils and the Cups, there was a fixed number of options for the children to consider but in the Bats and the Marbles activities the children had to generate their own options. In both the Gerbils and the Cups activities, the children had three possible choices to select from. Questions such as 'Do they consider the evidence for all three of these choices?' and ' Do they consider evidence for *and* against each of the homes/cups?' had to be addressed.

The transcripts were examined to see which options the children considered in the first two activities, the Gerbils and the Cups activities. As noted before, there were three possible choices in both activities that the children could consider. For example, St Anne's Group 2 explored the options for and against all three cups in the Cups, as indicated in Tables 6.4 and 6.5.

Table 6.4 Choices explored in the Cups by St Anne's Group 2

Choices explored by the children	Thin plastic cup	Thick plastic cup	Glass cup
Did the group discuss the advantages of this cup?	yes	yes	yes
Did the group discuss the disadvantages of this cup?	yes	yes	yes

In contrast, Woodstreet Junior School Group 1, did not consider the options for taking a glass on a picnic nor did they discuss any evidence against the thick plastic cup as Table 6.5 indicates.

Table 6.5 Choices explored in the Cups by Woodstreet Junior Group 1

Choices explored by the children	**Thin plastic cup**	**Thick plastic cup**	**Glass cup**
Did the group discuss the advantages of this cup?	yes	yes	**no**
Did the group discuss the disadvantages of this cup?	yes	**no**	yes

In the Bats and Marbles the group determined the number of options explored, as they had to make their own suggestions rather than consider choices presented to them. Counting the number of plans the groups discuss for dealing with the bats in the library and the number of explanations they suggest to account for the anomalous results in the Marbles show that some groups suggest more possibilities than other groups.

A numerical score was allocated to each group, showing the number of options a group considers in all four activities, as will now be explained. The possible number of alternative choices a group could consider in both the Gerbils and the Cups was six. Therefore, if each home or cup was considered and both advantages and disadvantages of each home or cup were discussed, a maximum score of 12 points was allocated to the group. For example, St Anne's Group 2 was awarded six points in the Cups (six x 'yes' in Table 6.4) and Woodstreet Junior Group1 was awarded four points (four x 'yes' in Table 6.5). This score was then added to the number of plans and alternative explanations considered by a group in the Bats and Marbles activities. Analysing the data using this technique illuminates the different ways the groups of children approached the decision- making process and the results for each group are considered in the next chapter.

The E number codes, the TAP analysis and the identification of the alternative choices considered, all provided an insight as to how evidence was used by the different groups of children. However, these techniques did not provide the detail that could show the ways children discussed evidence as a group. Mercer (1996) shows in his research that it is possible to analyse children's discussions to show different types of talk; some types of talk are good for solving problems and advancing whilst others are not. Another level of analysis was needed to facilitate an understanding of the collaborative relationship between the group members as will now be explained.

6.5. Identifying group arguments

A group argument depicts the elements of an argument that could be used to justify the final conclusion or choice made by a group. As described in section 6.3, an argument in its simplest form, comprises a claim and an appeal to data. Warrants can also be used to add further support to the argument as they explain the link between the claim and the data.

The scheme constructed to show a group argument has been adapted from Eichinger et al.'s model argument (1991). The model arguments illustrate the possible arguments that could be constructed from the evidence available. An example of how this scheme was used for this research is given below to demonstrate how evidence can be used to support claims both for and against alternative choices. However, before this example is discussed it is important to appreciate what a model argument is and how it was constructed for the research reported in this thesis.

6.5.1 Defining the model argument

The model arguments adopted to analyse children's discussions included the following elements:

- The claim is the final choice made by the group.
- The data appealed to explain why this choice has been made.
- The warrants explain why the data support the claim.

- If the data supplied are incomplete it may be necessary to specify the conditions under which the conclusion is warranted; this is the qualifier.

The emphasis for this research was *how* the children used evidence to make their decisions and therefore the validity of their claim or conclusion could depend on the qualifiers used. This can best be illustrated by the following examples of model arguments from the Gerbils.

6.5.2 An example of a 'model argument'

The model argument for the Gerbils is shown in Figure 6.1 A - C and illustrates three arguments. The claim in argument A is *for* Home 3, the claim in argument B is *against* Home 1, and in argument C the claim is *against* Home 2 as choices for a home suitable for gerbils. The qualifier is that the decision should be based on what is the best for the gerbil (rather than cost or convenience); the data should be the best conditions in which to keep pet animals. Thus the data that should be appealed to are the conditions in a cage that are most like the animals' natural environment (Dunphy et al., 1993). For gerbils this means a home in which they can burrow, have enough room for more than one gerbil as they are social animals and one that does not have parts made of plastic, which they chew. A wheel is inappropriate for gerbils as their long tails get stuck in the spokes. In argument A, the warrants indicate that since Home 3 provides these conditions it must be the best choice. Arguments B and C include claims are that Homes 1 and 2 are not good choices, respectively, as they do not provide the right conditions that gerbils need.

Figure 6.1C Model argument against choosing Home 1

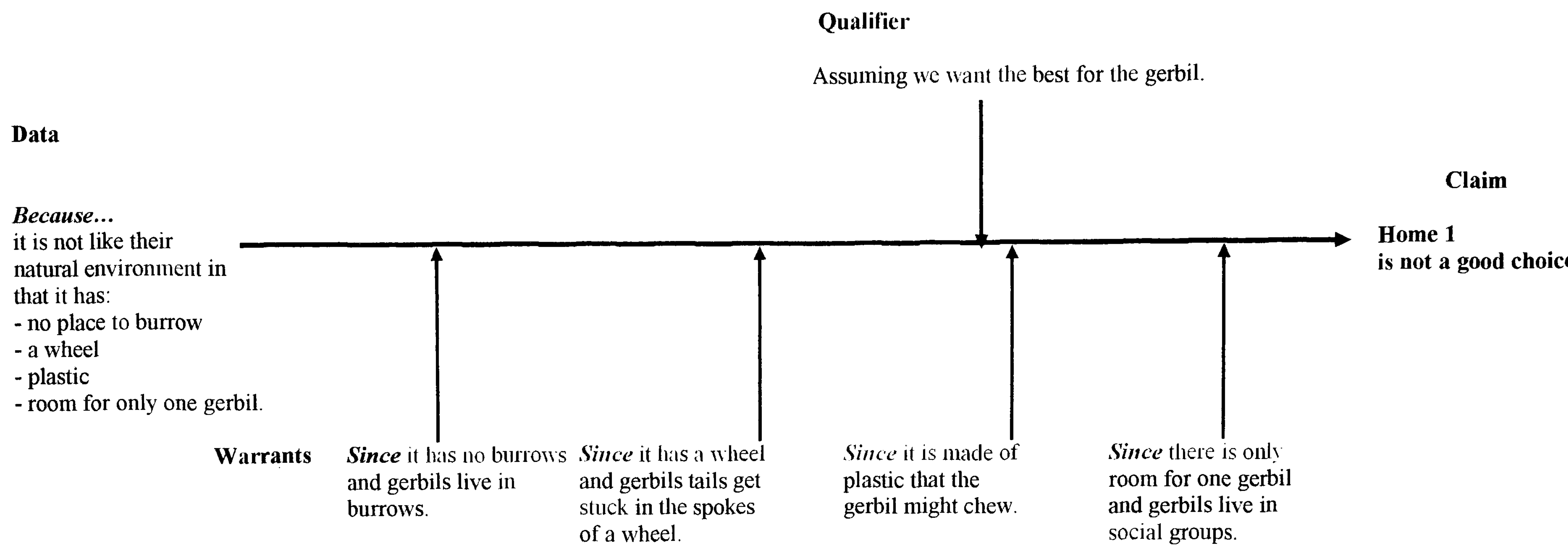


Figure 6.1B Model argument against choosing Home 2

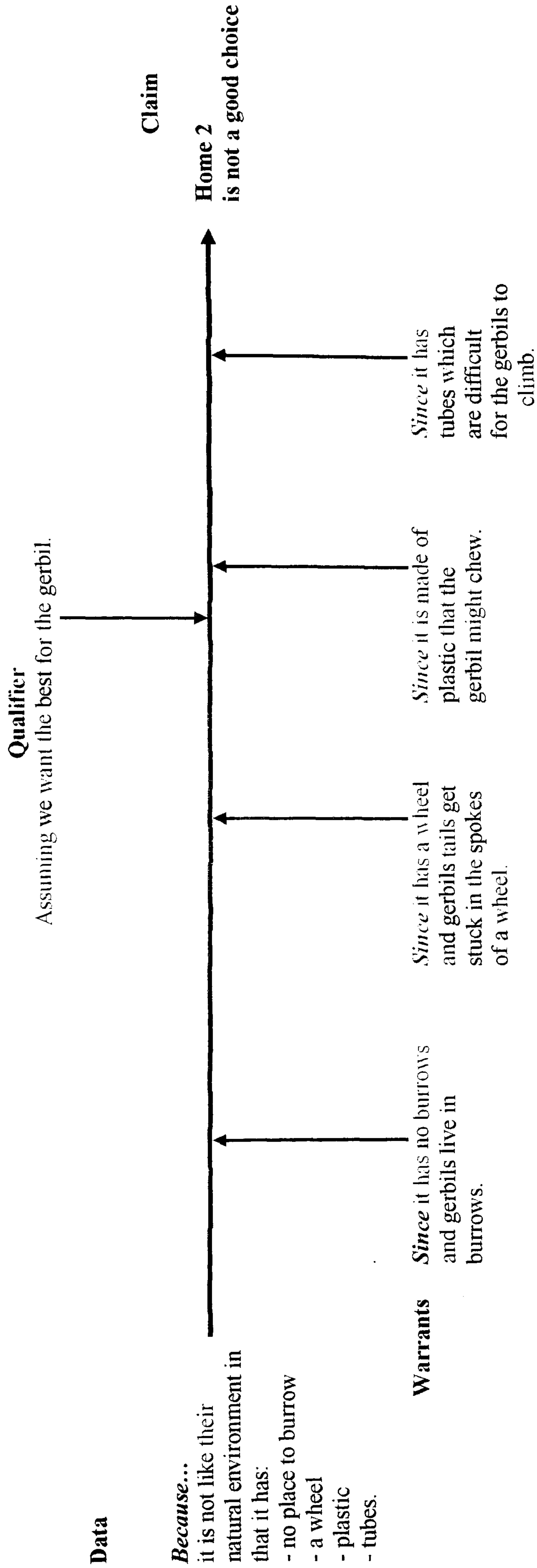
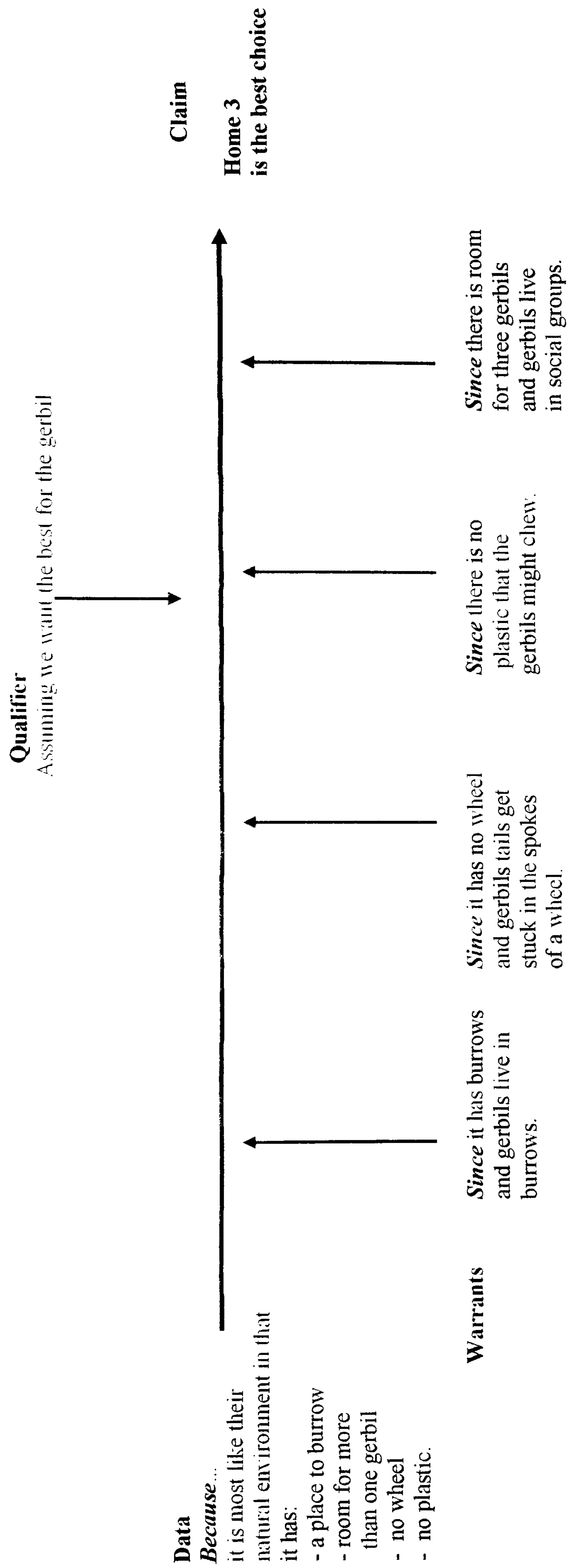


Figure 6.1A Model argument for choosing Home 3



However, the children may base their arguments on a different qualifier, for example, on how easy the cage is to clean out. In this case the data are that the design of the cages and materials used to construct them make the cages easy to clean. Since Home 1 is a simple structure and is easy to clean then it follows that it is the best choice of home for the gerbils. The warrants are that Home 1 is easy to dismantle and is made of plastic that is easy to wash. Home 2, although made of plastic, has a complex structure as it consists of different layers and would be more difficult to clean. Home 3 is made of glass and could be easily broken. It has layers of sand and gravel and would be more difficult to clean. (Although Home 3 would require more care when cleaning, it does not need cleaning out very often and is still the best choice of home for gerbils.)

Evaluating each group's discussion against the model argument scheme enables the number of arguments the groups construct and the warrants used to be identified. This analysis will demonstrate the range of approaches children take when using evidence to make a decision. It will show which evidence they used and from where they drew this evidence and will confirm the number of alternative choices considered.

6.6 Identifying patterns of argumentation in the group discussion

The final analytical scheme to be devised was the discussion map, introduced in section 6.2. The original aim of this analysis was to produce diagrams to represent visually the pattern of the discussions, to shed light on the ways children argue and use evidence. The discussions vary in length, for example one transcript was one page in length and another was 24 pages in length. However, the length of the transcript does not indicate anything about the process of the discussion.

The pattern of the argumentation might show a group takes one claim and discusses its merits before moving on to consider another claim, or alternatively, that they expect each member of the group to make a claim before the merits of each claim is explored.

In other words, is it a dialogic process where the children are bringing together, and working on, their ideas (Mortimer and Scott 2003)? To facilitate the study of the discussion to show different approaches, a coding system was devised to show an overall pattern of the discussion rather than its substance. The discussion maps were designed to show whether the children engaged in sustained dialogue by making claims, reviewing evidence and discussing arguments as an iterative process or if the discussions were brief, unconnected and claims were made unchallenged. The construction of these maps was informed by the work of Chinn and Anderson (1998) using 'argument networks'. The analysis of some of the pilot study transcripts to show argument networks, helped establish the importance of mapping out the main features of a discussion.

6.6.1 Identifying argument networks

Chinn and Anderson (1998) analysed the structure of discourse of children in small groups when discussing issues raised by stories (not scientific in nature) the children had read. Chinn and Anderson developed a system for making diagrams of argument structures and to do this they employed two complementary approaches:

> The first approach, the argument network, represents argumentation within groups of students as an interlocking web of premises and conclusions. The second approach, the causal network, represents the argumentation primarily as events linked in a causally connected narrative sequence.
>
> (Chinn and Anderson, 1998: 315)

For the purposes of the research reported in this thesis, the argument network was considered most appropriate as it mapped out the features of the discussion by identifying the positions the children take in the argument and how they supported the claims they made. This helped to identify whether they used evidence in their arguments and also if the children responded to evidence when a counter-argument was put forward. The argument network was applied to two transcripts, which were from one group of pupils in two activities, the Gerbils and the Cups. To illustrate the process of how the argument network was applied in this research, a very short excerpt from the Cups is presented below and the corresponding argument network in Figure 6.2.

Extract 13

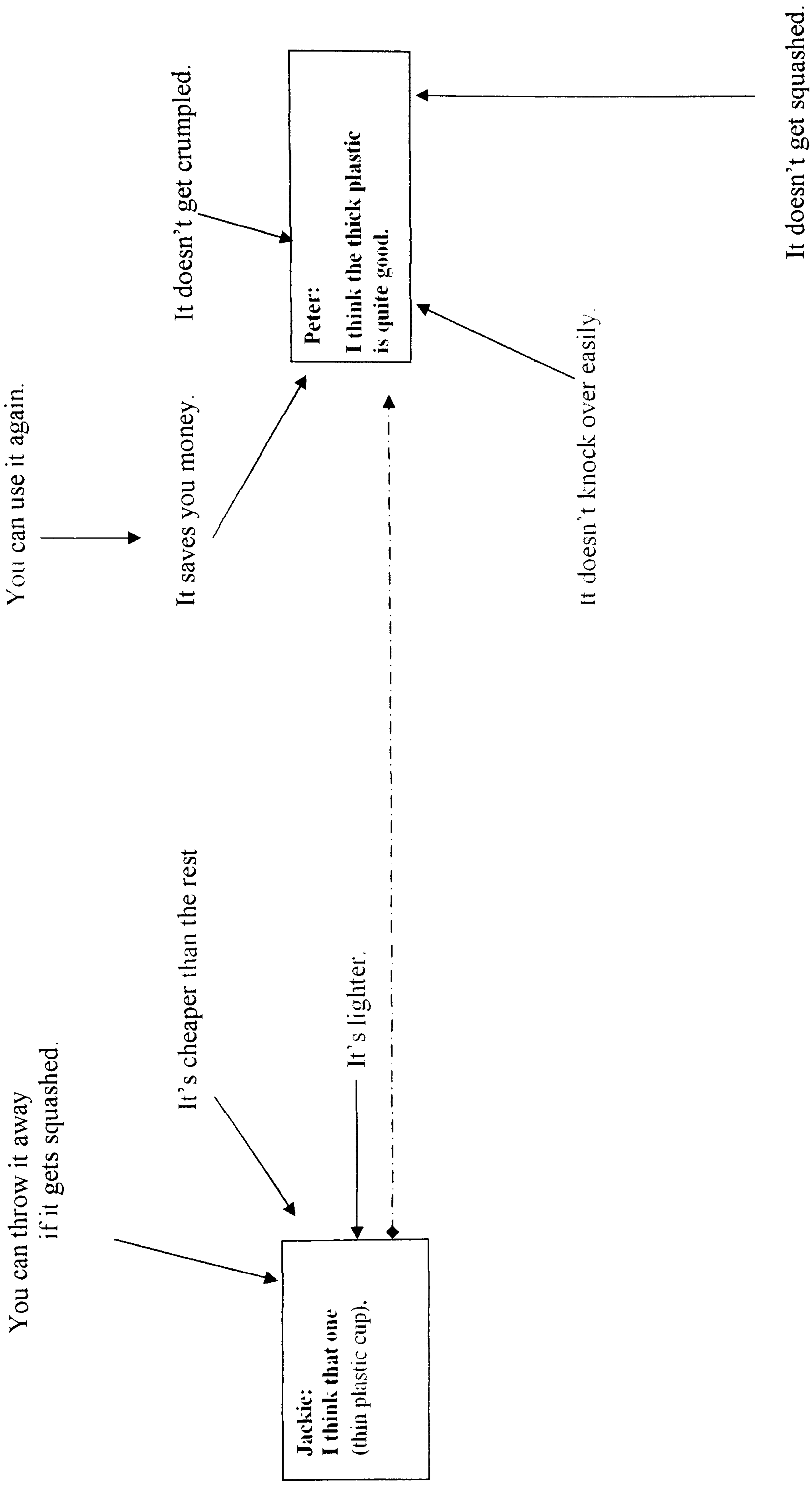
15. **Jackie**: I think that one (thin plastic cup) would be the best, you could throw it away afterwards, if it gets squashed and it's only... cheaper than the rest, and its lighter.
16. **Peter**: Well, I think the thick plastic's quite good 'cos you can use it again. It doesn't kind of get, well, knocked down easily and it doesn't get kind of ... squashed. It saves you money and it doesn't get crumpled so much and the one you suggested ...
17. **Jackie**: But, you might want to use this one because you might want to squash it afterwards, you might want to just squash it afterwards and put it in the bin after you've had your picnic.
18. **Peter**: But the thick plastic will save you money won't it?

The extract shows how two of the children, Jackie and Peter, make different claims at the beginning of the discussion. Jackie claims that the thin plastic cup would be best to take on a picnic and she gives several reasons why it is the best; the cup could be thrown away afterwards; it's cheaper than the rest and it's lighter (see line 15). Peter takes up a different position as he thinks that the thick plastic cup is best because you can use it again, it doesn't get knocked over easily, it would save money and doesn't get as crumpled as the thin plastic cup (see in line 16). In the argument network these claims, appear in rectangles as shown in Figure 6.2. Arrows to the rectangles indicate how a claim is supported. Links from one position to another, for example, from Jackie's claim to Peter's, are indicated by a dotted line.

An argument network was constructed from the transcripts of one group of children in two different contexts, the Gerbils and Cups. Two networks were constructed to see whether they could be used to see if children demonstrated the skills of using and evaluating evidence differently in different activities. One of the major problems encountered was of a practical nature; transcript 14, from which this extract was taken, was four pages in length but the argument network diagram required 13 pages. The extent of the diagrams also made the patterns of the argumentation within the different discussions very difficult to see, even though this had been one of the aims of the analysis.

However, constructing the argument networks ensured that the transcripts were read very carefully which in turn ensured greater familiarisation with the content of the discussions. This iterative process was helpful in judging the value of producing a diagrammatic analysis of the discussion and although the argument networks *per se* were not pursued further as a coding system for this research, the need for some diagrammatic representation of the discussions had been established. A diagrammatic representation could be helpful in showing whether there were varying patterns of discussion for the different activities. As a result of this pilot work and the developing clarity about the requirements to aid analysis, another coding system was examined to see if it could provide ideas for a simpler and more visual analysis. This coding system was termed the discussion maps and they are described in the following section.

Figure 6.2 Argument network for excerpt from the pilot study data (the Cups)



6.6.2 Constructing discussion maps

Drawing on the ideas of the argument network a scheme was devised which identified the pattern of the discussion. This scheme indicated the way the children engaged in the discussion and is termed a 'Discussion Map'. Preliminary analysis of the transcripts resulted in four units of 'talk' being identified. These units were termed *Review, Discussion, Argument* and *Clarification*. The characteristics used to define these episodes of the children's discussions along with examples of each category are shown in Table 6.6.

Table 6.6 Characteristics of the Four Types of Talk

	Characteristics of the sequence	Example
Review	Children read out sections from the information sheets or state evidence without constructing an argument. *In this extract the children are reading the Bat Fact? Cards but making no comments on what they are reading.*	**Luke and Sheerah**: Bat droppings can be a nuisance. **Sheerah:** They can make a mess on cars **Naveed:** Yes sometimes there are problems. **Luke: ...** Windows and things stored in lofts. But the droppings are only made of insect skeletons and crumble into a powder. **Naveed:** Oh look they can ... their urine can damage polished wooden surfaces. This is sometimes ... **Osei:** Although bats only produced small amounts of urine, it can damage polished wooden surfaces. This is sometimes a problem in churches.
Discussion	Children confirm, elaborate ideas, make comments, oppositions and counter-oppositions. They may make incomplete arguments e.g. arguments which have claim but without an appeal to data. *In this extract Amy is talking about Home 1 for the gerbils. Jillese and Che elaborate on her idea that Home 3 is not a good choice for the gerbil. Che introduces Home 2 into the discussion but does not make a claim for choosing this home. Jillese considers Home 1 and makes a claim but with no appeal to data.*	**Amy:** This one is really small, really small ... (Home 3). **Jillese:** It hasn't got a wheel. **Amy**: It's not big enough. **Che**: Yes, and it ain't got nothing to run around in. **Jillese**: That's what I was going to say. **Che**: And it needs, it needs space that's why it can run up and down on this one as well (Home 2). **Amy**: Yeah. **Che**: It's got space. **Jillese**: But this one is okay (home 1). **Che**: It's okay. **Jillese**: It's a bit small though.
Argument	Children make a claim that is justified with reference to data. This is sometimes, but not often, supported with a warrant and backings. These are identified in the TAP analysis. *In this extract Junior claims that it is unfair that someone should be fined for killing or injuring a bat. The data to which appeals is that people might not have the money to pay the fine.*	**Junior**: I think that's unfair, for some people might not have that amount of money.
Clarification	Children ask questions of each other or of the researcher to clarify e.g. what had to be done, what was said or what was meant *In this extract Joanne asks the researcher if the home they need to choose is for more than one gerbil. The evidence she has says that Home 1 is only big enough for one hamster.*	**Joanne**: It's big enough for one gerbil (Home 1), well one gerbil, gerbils. Is that right? It says gerbils?

The first stage of constructing a discussion map required the identification of the arguments put forward. The arguments were identified using the TAP scheme as has been explained earlier in this chapter. When the children were exploring possible decisions, assertions or claims were made; when they were accompanied by justifications, this process was defined as making an argument for or against the choice (Kuhn 1991). Once the arguments had been documented the episodes of the discussion termed 'Clarification' and 'Review' were then identified. What remains of the talk is termed 'Discussion' and, although much of this includes a variety of types of talking (Mercer, 1996), it remains under one category for the purposes of the analysis. Mercer distinguishes between exploratory talk when the discussion is characterised by explanation and justification and disputational talk that is typified by assertions and counter assertions. Analysing the discussion at this linguistic level deals with the content of what was being said by the children. The first discussion maps drawn up were very simple as the extract shown in Figure 6.3 illustrates.

Figure 6.3 Prototype discussion map: Castle Hill Group

Clarification

↓

Discussion

↓

Argument 1

↓

Review

↓

Argument 2

↓

Review

↓

Argument 3

↓

continued

This simple flow diagram could be used to compare the order of the episodes of the children's discussions as it demonstrates whether the children always start with a review of the evidence or if they put forward an argument and then discuss. It also showed that some groups always sought clarification before starting the discussion but other groups did not ask any questions of the researcher or each other. However, this prototype map provided a rather limited amount of information so the maps were developed to provide more detail of the discussion but still facilitating easy visual comparisons.

As a result, a more informative style of discussion map was developed as shown in Figure 6.4. The map has four columns rather than the simple linear pattern of the original map. In order to indicate the different lengths of the discussions, the line numbers from the transcript have been added in column 1. Second, in column 2, the episodes are listed in sequence. Information regarding the nature of the episode has been introduced in column 3, for example, this might include what option the argument involved, (it could be supporting a choice for Home 1 or against the glass cup) or what issues needed clarification. Finally, the names of the children taking part in the discussions or putting forward an argument are identified (see column 4). This helps to identify which discussions were inclusive of all four children and also indicates if one child was taking a more active role than another.

This style of discussion map can be used to compare whether all the groups approach the activities in this way. For example, they show whether the children reviewed the evidence before they put forward an argument, whether they discussed the arguments put forward or if they ignored each other's arguments and just put forward their own. If opposing arguments had been put forward the maps indicate whether the evidence was reviewed to help them evaluate opposing claims. The maps were also used to show which children were taking part in the discussions. Discussions may involve all four children at once (see **All 4** in column 4) or just some of the group; the maps can be used to show if there is any difference in the number of children engaged in the discussions. The maps also show if some children dominated the discussion and if some children joined in discussions but did not put an argument forward. Where more children are involved in the discussions, there is likely to be a greater exchange of views. The data can then be examined to see whether the evidence is used more effectively when more children join in the discussions.

To make comparisons between the groups more systematic and not based on overall impressions of differences between the maps, the different patterns of the discussions were organised into different levels.

Figure 6.4 Discussion map

Gerbils: St Anne's Group 2

Children: Alicia (A), Daniel (D), Heidi (H), Junior (J).

1 **Lines**	2 **Episode**	3 **Notes and source of evidence used**	4 **Children**
14-22	**Review**	Reading information sheets on homes.	All 4
23-26	**Discussion**	How to choose a home.	J, A & H
27-28	**Argument 1**	C= I'd choose a home with room (not specific home). D=so it doesn't keep lounging about.	A
29	**Argument 2**	C= it's best for them to lounge about. D= because they don't come out in the day.	H
30-34	**Argument 3**	C= you need a sound proof cage. D=because you don't want them in another room.	H
35-36	**Argument 4**	C= I don't like H2. D= the holes are too small.	J
37-39	**Argument 5**	C= Home 2 & 3 might be good. D= because H1 hasn't got a lot of facilities.	H
40-41	**Review**	Reading out information on .	D, & A
42-46	**Discussion**	Home 2 looks good.	D,H & A
47-48	**Review**	Home 2 again.	D
49-58	**Discussion**	Home 2 is not safe.	H,J & A
59	**Review**	Home 2 again.	A
60-66	**Discussion**	Could choose H 3 but H 1 is good.	All 4
67	**Argument 6**	C= yes it does (exercise does matter). D= or they will grow too fat.	H
68-71	**Discussion**	H 1 is a possibility.	All 4
72-75	**Argument 7**	D= it's plastic. C= it can't break.	H
76-88	**Discussion**	Gerbils might hurt themselves on the wires in H2.	H,J & A
89	**Argument 8**	C= I don't like that. D= because it's true, like Alicia said, it could get stuck.	D
90 -106	**Discussion**	Not choose Home 2 . reinforcing claim against Home 2.	D H
107 - 111	**Finalising the activity**	Heidi asks if others have decided. She suggests they keep it a secret.	H
		End of discussion brought about by Heidi. ***She says she knows which she is choosing.*** ***She collects up the information sheets*** **NO DECISIONS MADE**	

6.7 Identifying levels of argumentation

The discussion maps show that the groups follow different patterns in their conversations and indicate that groups have different levels of sophistication in their approach to using the E1 evidence and the process of argumentation. At the simplest level a group will discuss the available evidence but will not use this evidence to make arguments. The most sophisticated level shown by the children demonstrates them engaging in a more complex procedure. It is an iterative process as they review and discuss the available evidence; the discussion leads to an argument that in turn engenders further discussion. The evidence then is examined further to see how it can support the arguments being put forward. The discussion eventually leads to the reinforcement or refinement of the original argument or the development of a new argument. Four different approaches have been identified each with increasing levels of sophistication. The levels identified are as follows:

Level 1. Discussion with few or no arguments
Evidence is discussed but not used to make arguments.

Level 2. Series of arguments
The children state their arguments one after the other. They take it in turns to say something. There is no discussion beforehand.

Level 3. Arguments with discussion
Type 3A:
The arguments are dispersed with discussion. The discussions concern the argument but may also include story-telling related to the argument

Type 3B:
The arguments are repeating the same points. The discussion is confirming points made, not challenging the arguments put forward

Level 4. Discussion leading to arguments
Type 4A:
Discussion leads to an argument but the following discussion is not related. There is no challenge to the argument it is just followed by a different argument.

Type 4B:
Discussion leads to an argument that engenders relevant discussion. The discussion relates to the previous argument and this leads to the reinforcement or refinement of the original argument or the development of a new argument.

Type 4C: Sustained Argumentation
Discussion leads to an argument that engenders discussion and *review of evidence*. This leads to the reinforcement or refinement of the argument or the development of a new argument. The process of evaluating new arguments is sustained throughout the conversation.

These levels have been used to identify the argumentation process followed by each group in the four activities. The maps were examined and levels were identified for the discussions. This task was repeated on three occasions, with some months apart. This action was taken to test the reliability of the application of the coding system. Where any differences occurred in the allocation of the codes, the coding process was repeated until agreement was met.

All the coding schemes discussed in the previous sections have related to analysing the way the groups of children used evidence. The following sections explain how the data were analysed to show how each individual child used evidence.

6.8 Identifying the individual arguments

As explained in previous chapters, this research aimed to find out how children reason and use evidence not just when they are working in a group but also when working as individuals. To determine whether children would use evidence in a different way when working on their own as they did in a group, each child was interviewed after each activity. The interview was designed to show if a child would:

a) justify the claims without prompting, and

b) use different evidence to that which had been discussed in the group.

At the beginning of each interview each child was asked the same question. This question is question 1 as shown in Table 6.7. Further questions were only asked if the child's answers did not justify the claims being made or if they did not explain why other choices had been rejected. These questions acted as prompts to scaffold the child's answers in order that evidence used in making decisions would be exposed in the interview. Children, whose reasons gave full answers to question 1 were not asked any further questions.

Table 6.7 Interview questions for the four activities

Interview questions for Gerbils
1. Now you have looked at the homes, which did you choose? 2. Can you tell me why you chose Home (number of home chosen)? 3. Can you tell me about Homes (numbers of homes not chosen)?
Interview questions for the Cups
1. Which cup would you take on the picnic? 2. Can you tell me why you chose this cup? 3. What about the other two cups?
Interview questions for the Bats
1. Can you tell me your first idea? 2. And have you changed your mind at all? 3. Can you explain what made you change your mind?
Interview questions for the Marbles
1. Can you tell me what you think has happened in this investigation? The questions that followed varied according to the children's interpretation of the situation.

Transcripts were made of all the interviews and the number of prompts each child had been given in order that they justified their claims was identified. This analysis revealed whether children, who did not make claims supported by data in group discussion, could in fact do so on their own or when prompted by relevant questioning. That is, whether they are capable of justifying their choices but only give support to claims when encouraged by someone else. For example, some children were only asked question 1 and needed no further prompts. Their answer included not only justification for the choice made but also reasons why the other alternative choices had been rejected. The following extract (Extract 11), from the transcript of the interview with Joanne after the

Gerbils, shows that Joanne gave a full answer to question 1 as she explained why she chose Home 3 and why both Homes 1 and 2 had been rejected. As a result, no further questions were required.

Extract 11

J. F. M: You have looked at the homes and which did you choose?
Joanne: Em I chose Home 3. Well, it isn't, well I thought it was a natural environment. Em ... I chose that one because, well, it was its natural environment for a gerbil. You could always put a wheel in it. And it's got everything that they would really need. The thing I didn't really like was that it was an old aquarium.

I didn't like Home 2, which was the big tall one, because I thought that as they get older, the gerbil gets older, it wouldn't want to run up and down. It would just get really tired and stay in the bottom part (of the cage) or something. And then you would have to buy another one, which isn't so active, if you know what I mean.

And the Home 1, I thought that was my second choice but it said it was a home for hamsters and it was only big enough for one gerbil. Which I thought wasn't very good because they wanted two gerbils, or three.

In contrast, Osei, in the same activity required several prompts before he offered a justification for his choice of home and explained why the other two homes had been rejected as the following extract illustrates:

Extract 12

J. F. M.: you have looked at the homes and which did you choose?
Osei: We chose Home 2.
(Long pause)
J.F.M: Home 2?
(Long pause)
J.F.M: Can you tell me why you chose Home 2?
Osei: Because it's got lots of space and loads of room for the gerbil to exercise and ... and ... if the gerbil has babies it can put it in each room.
(Pause)
And you can extend it with more tubes.
J.F.M: Is there anything else you want to tell me about Home 2?
(Pause)
J.F.M: OK. Can you tell me about Home 1 and Home 3?

Osei: We didn't use this one (Home 1) because we thought it was plain, and it didn't have...it only had that exercise wheel and a food bowl. We could extend it with an aquarium but it would just mean more money.
(Pause)
J. F. M.: So that's Home 1.
(Long pause)
J. F. M.: So what about Home 3?
Osei: Home 3 is very cheap. It doesn't look very good for the gerbil, it looks very boring.

As the above extract shows, Osei was able to support his claims with reference to relevant evidence but he had to be encouraged to do so. He had to be prompted to justify why he chose Home 2 and then, again, had to be pressed to explain why he had rejected Homes 1 and 3. However, in explaining why he had rejected these homes Osei did provide reasons why he did not like them without prompting and so it seems that once it was clear to Osei that he was expected to justify his decisions he would do so. The examination of the interview transcripts led to the definition of the following codes that were applied to the data.

Table 6.8 Codes for the prompts required in the interviews

Code	Prompts required
A	Needs constant prompts throughout the interview, to provide justification for choices/decisions, to consider alternatives and to explain why alternatives were rejected.
B	Needs some prompts, usually at the beginning of the interview, to provide justification for choices/decisions or to consider alternatives but does give justification for some answers without prompts.
C	Gives justification for the choices/decisions, considers alternatives and justifies why the alternative choices were rejected without any prompts.

Finally the transcripts of the discussions and the interviews were examined to determine if the children used different evidence to support their claims in the interview to that which was discussed in the group. Such analysis helps to identify any differences in behaviour between group work and individual work.

Conclusion

The method of preparing the transcripts in the pilot phase not only showed that the same technique could be adopted for the main study but also that the recording technique and data collection methods need not be changed. Beginning the analysis with the pilot study data demonstrated where techniques needed to be refined to make them more manageable and also showed where new techniques were required. The analytical framework, derived from Mitchell's (2001) parameters for identifying good argumentation, was shown to provide a useful structure for analysing the data as the answers to the research questions can be found using the coding schemes developed. Analysing the data in different layers allows the relatively simple questions such as 'How much of the evidence is discussed?' to be answered as well as the more complex questions regarding the engagement of the group in the discussion.

Summary

This chapter has explained the basis for the analytical framework adopted in this research. The coding schemes selected have been described and examples have been given to illustrate their effectiveness in answering the research questions. The next chapter makes a detailed examination of the findings in order to see what arguments the children put forward and whether they used evidence to justify their claims. The findings are also explored to see what source of evidence the children use to support their claims and the number of options the group considers. The levels of argumentation each group demonstrates is examined. Finally, how children use evidence as individuals is compared to the way they behave in the group discussion.

Chapter 7 The findings: how children use evidence in discussions

7.0 Introduction

In chapters 5 and 6 the research methods were explained, the analytical framework was introduced and the coding schemes used for analysing the data were exemplified. The aim of this chapter is to use this analytical framework to examine the data in order to show how children argue and make use of evidence in scientific decision-making activities.

The data suggest that there are two key factors influencing the way children use evidence, the nature of the group and the type of the activity. The analysis reveals that children's performance varies due to the interplay between these two factors, but that the variable of the group has a greater influence on the way they make use of evidence.

Results from the four aspects of data analysis are presented in this chapter. The findings reveal that children, aged ten to eleven years old, demonstrate a range of skills in using and evaluating evidence. Some children review most of the information given to them in the decision-making activities, whilst others appear to ignore much of the information. Results demonstrate that children are capable of making claims supported by evidence, and they can engage in the elaboration of each other's arguments without the intervention of a teacher. The findings show that some children explore all the alternative choices in their discussions whilst others only explore some of the alternative choices.

The data indicate that children's argumentation skills vary. Some children discuss each other's ideas and expect evidence to be used to justify claims made. Other children merely put forward their own views and do not expect to be challenged or to oppose another child's claim with counter arguments.

As discussed previously, the data indicate that the roles adopted by the children had a key influence on the way the groups discussed and used evidence. Consequently, a new level of analysis was developed and details of the coding schemes devised for this aspect of analysis are given in chapter 8. However, in order to explain further how the presentation of the findings is organised, this current chapter begins with a reminder of the aims of the study.

7.1 The research aims and the relevant coding schemes

In chapter 5 it was established that this research had two main aims.

To find out:

- how children reason and make use of evidence to justify the decisions they take when working in a group;
- how they reason and make use of evidence to justify the decisions they take when working as individuals.

From these aims, other more specific questions were addressed which focused on the amount of evidence reviewed, whether it was used to justify claims and whether the format of the evidence influenced the group's interaction with the information provided. Other questions concerned the quality of the group's argumentation and how the children's performance in group situations compared with their performance as an individual.

As explained in the previous chapter, the analytical framework comprised a set of coding techniques designed to characterise how children make use of evidence when working on decision-making activities in science. The coding techniques included both simple quantitative data analysis as well as qualitative analysis. The findings from the data analysis are presented in two parts; first, the focus is on how the groups of children made use of evidence and, second, on how children made use of evidence when working alone.

7.2 Key findings of how children use evidence when working in groups

In chapter 2, it was established that people need to develop skills in order to be able to evaluate and assess new information so they can make rational decisions. In this research, children were given information to use in four different decision-making activities and the results show that children, aged ten to eleven years old, make use of information and approach the process of decision-making with widely different levels of sophistication.

The analysis focuses mainly on the different groups and what might influence their performance. However, as will be seen, aspects of the task may also determine the nature of the interaction. Hence, the argumentation results from a complex interaction between the group and the task.

In order to analyse how children made use of evidence when working as a group, the findings from the following coding schemes were used:

- E number codes: the source of evidence;
- TAP analysis: claims supported by evidence;
- Model arguments: the group argument for the final choice;
- Alternative choices: the number of alternatives considered;
- Levels of argumentation: the pattern of the group discussion.

The findings drawn from the above schemes demonstrate that of the five groups of children involved in this research, the Castle Hill Group reviewed the widest range of evidence, justified more claims with evidence and explored the greatest number of alternative choices. Their discussions incorporated sustained argumentation where arguments were reviewed and evaluated before decisions were reached. This group's approach to decision-making activities was consistent for all activities. In contrast, another group of children, from the Woodstreet Junior School, reviewed little of the evidence made available and consequently much of the evidence used to support their arguments was drawn from their own experiences. Many of the arguments put forward by these children were repetitive and as a result, much of the evidence used to support the arguments was the same and little use was made of the information given to them. They made little attempt to evaluate arguments or to discuss how the arguments put forward in the discussions impinged on their decision

These findings are now presented in detail to show how the data provides insights into the ways children reason together and the use they made of evidence when making decisions.

7.3 Results of the analysis of the amount of E1 evidence reviewed

The data presented in this section concerns the amount of evidence provided (E1 evidence) was reviewed by each group. The factors that influence the amount of evidence reviewed are then discussed.

7.3.1 The percentage of E1 evidence reviewed

The analysis shows that although the same E1 evidence was made available to each group and the videotapes show that each group read (to themselves and/or aloud) *all* the E1 evidence given to them, the groups of children referred to different amounts of evidence in their discussions. The actual amount of evidence discussed by the children has been calculated, as each activity had a set amount of information provided. For example, in the Gerbils, 18 separate pieces of E1 evidence have been identified. Pieces of evidence include statements in the information given to the children, such as, that gerbil Home 1 'is made for hamsters' or they might refer to the picture of Home 3 where there are three gerbils in the burrows (full details of the evidence referred to in each discussion are given in Appendix 10).

The amount of E1 evidence discussed by the groups of children in each activity is presented in Table 7.1. The figures give the number of the pieces of evidence discussed by the children, out of the total number of pieces of evidence given to them (n). These figures are also given as a percentage in order to see if the use of evidence varied with the activity.

Table 7.1 The percentage of E1 evidence reviewed by the children in each activity

Row	Group	E1 evidence presented in the form of information and pictures		E1 evidence presented in the form of a report and tables of figures	
		Gerbils n=18	Bats n=14	Cups n=12	Marbles n=16
1	St Anne's Group 1	7/18 **39%**	12/14 **86%**	5/12 **42%**	6/16 **38%**
2	St Anne's Group 2	4/18 **22%**	10/14 **71%**	11/12 **92%**	5/16 **61%**
3	Castle Hill Group	14/18 **78%**	11/14 **79%**	9/12 **75%**	12/16 **75%**
4	Woodstreet Junior Group 1	10/18 **56%**	13/14 **93%**	1/12 **8%**	8/16 **50%**
5	Woodstreet Junior Group 2	3/18 **17%**	11/14 **79%**	4/12 **33%**	8/16 **50%**

Chart 1 presents these data to illustrate the differences between the amounts of E1 evidence reviewed by the groups of children.

Chart 1: The amount of E1 evidence reviewed by the groups

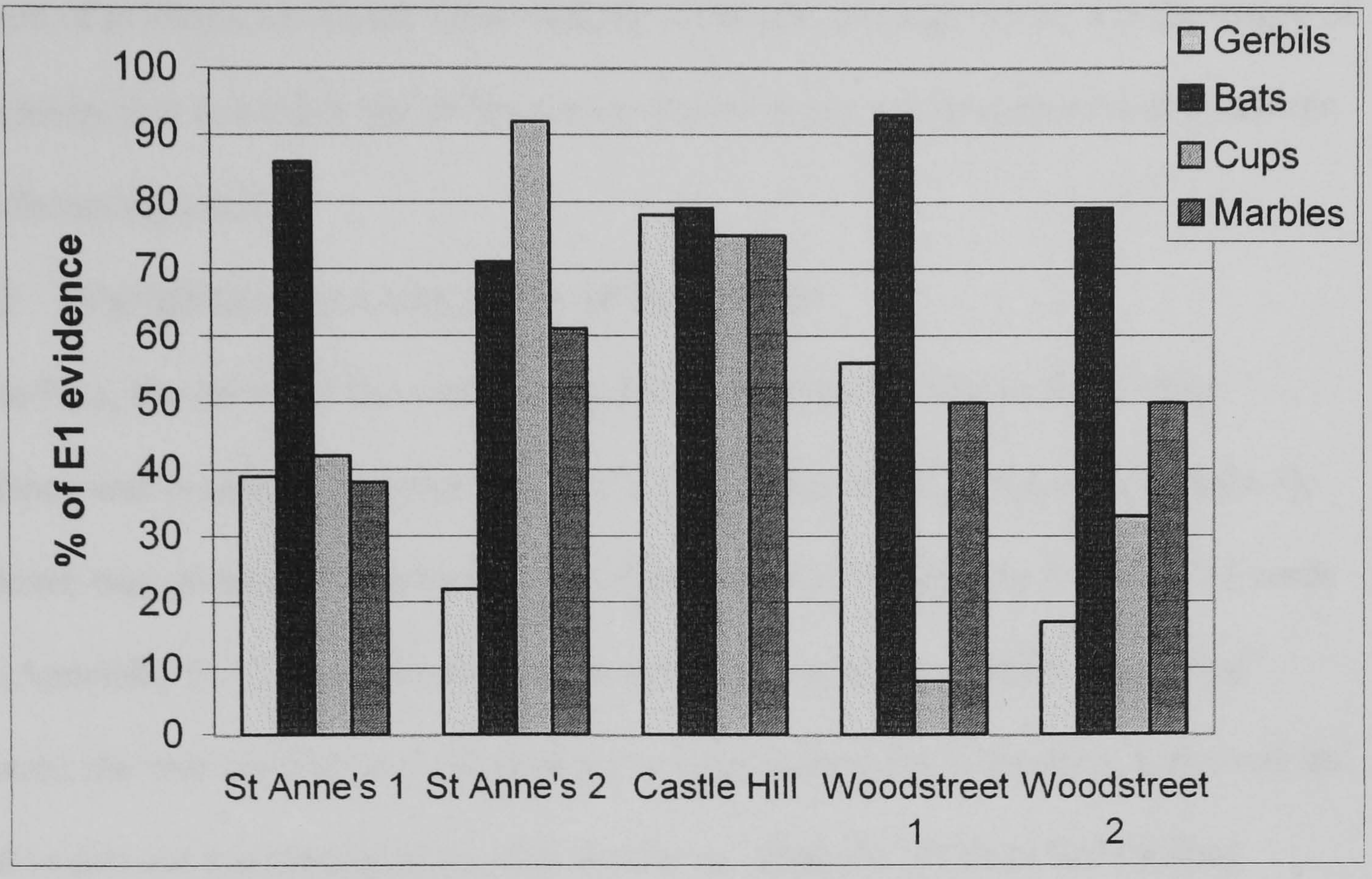


Chart 1 illustrates that the Castle Hill Group showed a measure of consistency in the way they made use of the available evidence in discussion as they used between 75% and 79% of the E1 evidence in all four activities. The other four groups discussed a variable amount of evidence in each activity, with Woodstreet Junior Group 1 having the greatest variation. The chart shows this group had a wide variation between the amount of evidence discussed in the Bats and the Cups; they discussed 93% of the E1 evidence in the Bats but only 8% in the Cups. These results suggest that the nature of the group has an important influence on the ways evidence is used. However, there is some indication that the nature of the activity also affects the ways the children use evidence as will now be explained.

The chart shows that there is an increase in the amount of evidence reviewed between the Gerbils and Bats by all the groups. In both these activities evidence was presented in the form of information and pictures, not in a table of data. These data suggest two possible reasons for this difference: either the difference is caused by a development in the children's skills or the nature of the activity has an affect on the amount of evidence reviewed. Observations of the groups suggest that it is the nature of the activity that has led to the differences as the evidence was presented to the children in different amounts.

7.3.2 Variability due to the nature of the activity

In the Bats, the nature of the activity was different to the Gerbils; in the Gerbils evidence was presented on three sheets of A4 paper but in the Bats (see Appendix 3), evidence was given to the children in small amounts on 14 separate *BAT FACT?* cards (see Appendix 5). Thus, in the Gerbils, the three pieces of paper had to be shared between the four children and required some organisation but in the Bats, there was no need to sort out the sharing of the information as, when the children had finished reading a card, they could just pick up another one. In an activity where E1 evidence is easily shared, there is a better opportunity for each child to review this evidence.

If children do not share the information given to them then they do not give themselves the opportunity to evaluate the importance of all the evidence. As discussed in chapter 2, if people merely adopt a view or opinion without considering the evidence themselves, they are not engaging effectively in any debate. Children need to be able to justify why evidence has been rejected, or has not been seen as important. As can be seen from these results, some groups discuss less than 50% of the E1 evidence provided. If children are to develop the ability to make rational decisions based on available evidence they need to acquire the habit of reviewing all or most of the evidence they have been given.

The consistency of the data for the Castle Hill Group suggests that the children have acquired the habit of considering much of the information given to them. The other groups do not have a consistent approach to decision-making as they demonstrate such variation in the amount of evidence discussed. This consistent approach to the review of evidence could be due to a number of factors. As explained in chapter 5, children at Castle Hill School are encouraged to work together in co-operative, problem-solving teams, and this factor may have a bearing on the way this group works together. This aspect is discussed more fully in chapter 8.

Other possible factors to account for the differences in the way the other groups of children discuss evidence could include the children's knowledge and previous experience of the issues and the motivations of the individual children. For example, Bridges (1979) describes people unable to take part in discussions simply because they do not know anything about the subject or may think they have no relevant ideas or knowledge. The following sections examine how previous experience, and the children's motivations, may have influenced the way the groups of children discussed the E1 evidence.

7.3.3 Prior experience and its possible effect on the amount of evidence discussed

Of the four activities, it is likely that the children would have had the greatest variation in relevant experience in the Gerbils, as some may have had pets and others may not. Similarly, it is possible that children could have some understanding of how bats are protected by the law if they lived in an area where bats were causing problems, for example, in a local church or even in their own homes. Children are likely to have very similar experiences of using the different types of cup, as all the cups used in this activity would be found in most domestic situations. The children all had the model tubes to look at and touch in the Marbles and the coverings were made from familiar materials.

The prior experience of the children can be identified in their discussions. The transcripts show that none of the children had any experience of dealing with bats or any prior understanding of the law concerning bat protection. This lack of experience was shown in the children's plans formulated before the evidence was made available that included removing the bats, poisoning the bats and catching the bats in nets or cages. All these actions are illegal and subject to heavy fines. Another indication that suggests the children had little prior experience is that all groups reviewed most of the E1 evidence in the Bats, possibly because the children required as much information as possible before they could make any decisions.

From the transcripts of the Gerbils, it was easy to identify that some of the children had experience of keeping small mammals as pets as they made it clear by the statements they made. As the following extract shows, Jillese and Amy in Woodstreet Junior Group 1 indicated that they had pet hamsters:

Extract 1

141. **Jillese**: I had a hamster and I had this little truck thing and it moved about. But it started to bite the plastic.
142. **Amy**: But look, look, if you get one of those tiny houses you can't even put one in there (Home 1).
143. **Che**: Yes, because … it …, you can just put in the house in there (Home 2).
144. **Amy**: Yes, then …
145. **Che**: And when it comes out it could just run around.
146. **Amy**: That's big enough, that's big enough. This, the second one, (Home2), I've kind of got …
147. **Patrick**: Yes, that one's good.
148. **Che**: It's like, my friend had a hamster and she had one of these and she kept buying things to make it bigger, bigger and bigger.
149. **Amy**: Yes, I've got tubes coming out of mine.

The transcripts show that, except for St Anne's Group 1, each group had one or more members who had experience of keeping pets. The figures presented in Table 7. 2 give the amount of evidence discussed by a group and the number of children in the group who had experience of keeping pets. The figures are arranged with the group who reviewed the most E1 evidence in row 1, and the group who reviewed the least E1 evidence in row 5.

Table 7.2 E1 evidence reviewed and prior experience of keeping pets

Row	Group	% Evidence reviewed in discussions (n=18)	Number of children who had kept pets
1	Castle Hill Group	(14/18) 78%	2
2	Woodstreet Junior Group 1	(10/18) 56%	2
3	St Anne's Group 1	(7/18) 39%	0
4	St Anne's Group 2	(4/18) 22%	1
5	Woodstreet Junior Group 2	(3/18) 17%	0

Although caution must be taken when comparing the amount of evidence (n=18) used in percentages, when just one piece of evidence represents over 5%, the data do appear to indicate a possible link between prior experience of keeping pets and the amount of evidence referred to in the discussion. The groups that included two children with experience of having pets (rows 1 and 2) used the most evidence and, in the group that used the least amount of evidence, there were no children with experience of keeping pets (row 5).

Another factor to account for the variation in E1 evidence discussed is the influence of the individual child. As row 4 shows, in St Anne's Group 2 there is one child who has kept small pets at home yet the group uses less E1 evidence than St Anne's Group 1 where no children had had experience of keeping pets. Detailed examination of the transcript indicates that the role this child, Heidi, adopted has an important effect on the way evidence was used in the discussion as the following section explains.

7.3.4 Influence of the individual children and their motivation

The transcript reveals that Heidi, from St Anne's Group 2, was the only child in her group to have experience of looking after small pets but it also shows that, although Heidi knew which home to choose (Home 3), she influenced the others to make a different choice. In the interview Heidi stated that she had chosen Home 3, but in the discussion she guided the others *not* to choose Home 3. For example, when Daniel suggested he might choose Home 3, Heidi pointed out that it did not have an exercise wheel, thus making Daniel reconsider his choice. When Junior argued that a wheel doesn't really matter, Heidi responded by saying that a wheel does matter as, without a wheel, the gerbil would get too fat. As a result of Heidi's interventions only one of the seven pieces of evidence about Home 3 was discussed.

Heidi's behaviour affected the way other members of the group made their decisions. In the interview, Daniel, Junior and Alicia all chose Home 1, and justified this choice because the home had an exercise wheel. These decisions indicate how influential Heidi has been in directing these children away from choosing the only home without a wheel, Home 3, possibly because she wanted to be the only one with the correct answer. In the interview, Heidi chose Home 3, which is the most suitable home for gerbils.

In addition, when the videotapes are examined, Heidi can be seen suppressing the discussion about the children's final choice of home in order that she would not have to reveal her choice. The discussion shown in Extract 2 illustrates how Heidi directed the group to keep their decision about the home secret and this was the only group not to make their choices known openly in any of the discussions.

Extract 2

100. **Heidi**: You know which one you are choosing?
101. **Alicia**: Yes.
102. **Junior**: Yes.
103. **Heidi**: It's best to just keep it … you know? (*gestures with her arms to keep it down i.e. a secret*).
104. **Alicia**: O. K.

The role Heidi adopted in suppressing the discussion may account for the limited amount of evidence used by this group. During the data analysis it became clear that other roles children adopt in discussions was an important feature of how evidence was used by a group. These roles will be discussed more fully in the next chapter.

The data presented so far have considered whether the children reviewed the evidence in their discussions. However, evidence can be reviewed and yet not influence the decision made by the way children. To see if the evidence had influenced the final choices made by the groups it is necessary to identify what evidence was used to justify claims made. First, the individual arguments of the children were identified. As described in chapter 6, the arguments were identified using Toulmin's (1958) argument pattern and the number of claims made by the groups in each activity is discussed in the next section.

7.4 Results of the analysis of the number of claims supported by evidence

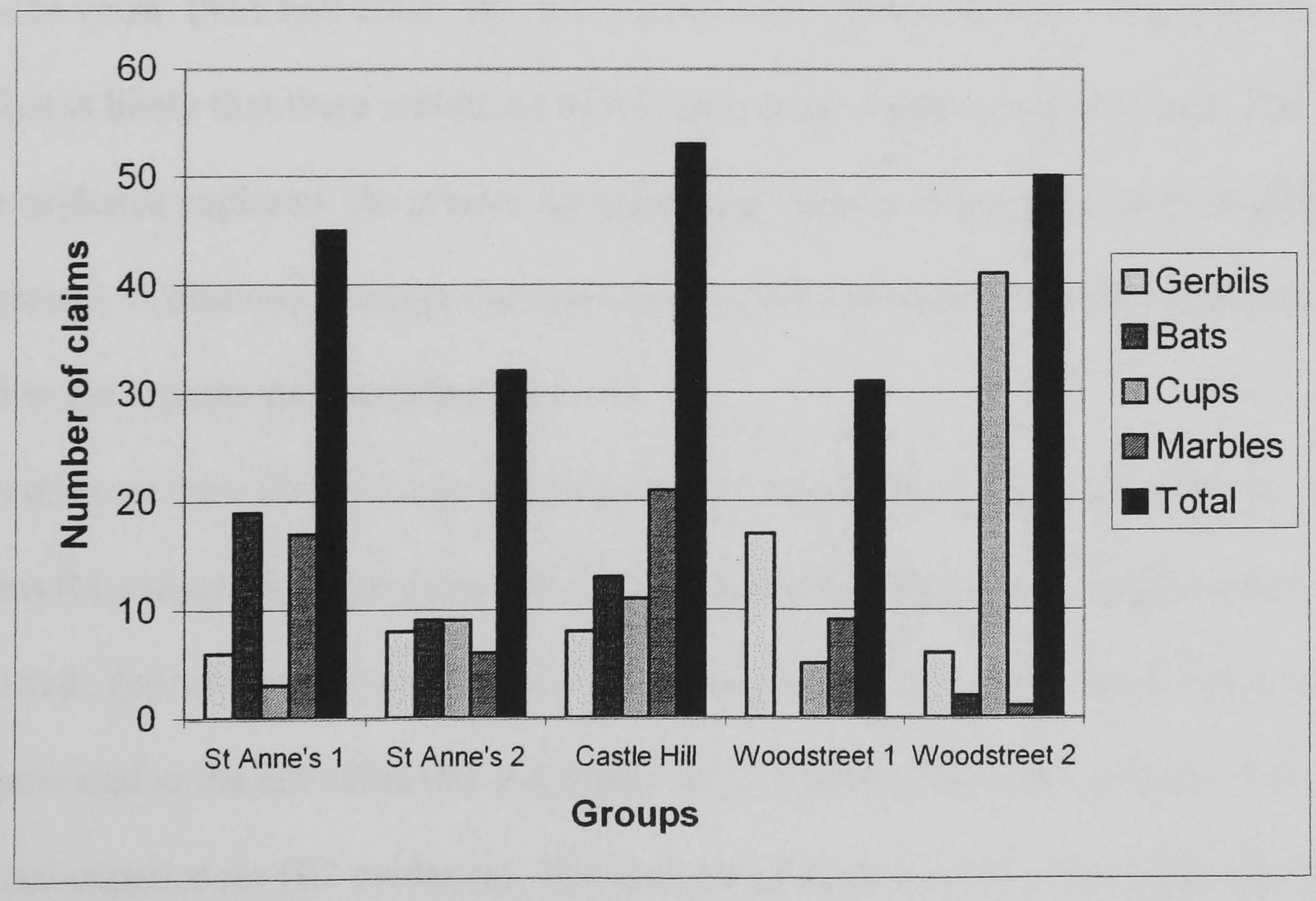
In decision-making activities choices have to be made and the ensuing discussion may include a number of claims and counter claims for different choices. As discussed in chapter 6, to argue for or against a claim, evidence must be cited. Evidence can be used to construct arguments to support or refute claims.

It has previously been explained that two forms of argument, identified by Toulmin (1958), were found in the transcripts. In the first type of argument, the claim is made and justified afterwards and in the second type of argument, the claim is made as a consequence of some facts or opinions having been stated. Both types of argument are analysed and the data, given in Table 7.3, show the number of claims, supported by evidence, made by the five groups of children. The data are presented in Chart 2 below.

Table 7.3 Number of claims supported by evidence in each activity

Row	Group	Gerbils	Bats	Cups	Marbles	Total
1	**St Anne's Group 1**	6	19	3	17	**45**
2	**St Anne's Group 2**	8	9	9	6	**32**
3	**Castle Hill Group**	8	13	11	21	**53**
4	**Woodstreet Junior Group 1**	17	0	5	9	**31**
5	**Woodstreet Junior Group 2**	6	2	41	1	**50**

Chart 2: The number of claims supported by evidence in each activity



It can be seen from chart 2 that the Castle Hill Group and the Woodstreet Junior Group 2 both make 50 or more justified claims. However, 41 of the 50 claims made by the children in Woodstreet Junior Group 2 were made in the Cups. Analysis of the transcripts reveals that many of the arguments were repeated over and over again. For example, the justification given for 17 of the 41 arguments made by the children referred to the unsuitability of the glass cup as it could smash and cut someone. A further seven arguments concerned other aspects of the safety of the cups. In contrast, the Castle Hill Group explored a wider range of criteria, for example, if the cups stack, how heavy they are, the cost of each cup, the insulating properties of the material as well as aspects of safety.

Therefore, the number of claims supported by evidence is not, by itself, necessarily an indicator of the quality of argumentation. Mitchell suggests that the exploration of *different types* of evidence is part of a good argument and that one of the practices that characterises good argumentation is the 'moving from wider to narrower perspectives and vice versa' (Mitchell 2001: 33). If the number of claims made in a discussion is small, it is likely that there will be a limited number of viewpoints to consider. The more evidence explored, the greater the possibility there is of having a range of different viewpoints. A discussion where the same evidence is used over and over again will result in the arguments also being repeated.

First, to see how the evidence used to support claims affects the argumentation process the transcripts were examined and the evidence used in each argument was identified. There were two sources of evidence available to the children; evidence that was provided in the activities (E1 evidence) and evidence which drew on their own personal experiences (E2 evidence). The analysis of the transcripts show that children drew on both sources of evidence to support their claims and the next section considers whether they drew on one source more than the other.

7.5 Results of the analysis of the source of evidence used to support claims

The source of evidence used by the different groups to support their arguments has been documented to see if the groups placed more emphasis on the evidence presented to them or evidence from their own or another's experiences.

When E1 evidence is used in an argument to support a claim, there are two implications. First, that the child thought the piece of evidence was significant and, second, that it provided justification for a claim or decision. Evidence regarded as unimportant may have been read and then ignored.

The results indicate that the children used both E1 evidence and also drew on E2 evidence. The E2 evidence used by the children included information brought into the discussion by another child, information from the teacher/researcher and also their accounts of experiences of family and friends. Table 7.4 shows the source of evidence used to support and justify claims for each group in each acitivy. For example, row 2 shows that of the eight arguments put forward by St Anne's Group 2 in the Gerbils, one claim was justified using E1 evidence, six claims were justified using E2 evidence, and one claim was justified using evidence from E1 *and* E2 together.

The results suggest that children draw on a mixture of evidence to support their claims, although the data for the Cups show that some groups were more influenced by their own experiences than the information given to them. Here, three groups, (see rows 2, 3 and 5) used considerably more E2 evidence than E1 to support their arguments. The evidence often concerned children's past experiences with cutting themselves on glass, as described in section 7.4 and these memories appear to be very important to the children.

As no other pattern emerges from the data presented in Table 7.4 it would suggest that children do not seem to be influenced by the format in which evidence is presented to them; whether the evidence is in the form of tables of figures, pictures or information does not appear to affect the way evidence is used. This finding would suggest that activities involving children in analysing scientific data and interpreting information could be used to develop children's argumentation skills. Teachers could plan activities where the evidence available is in the form of reports and newspaper articles on socio-scientific issues relevant to children, for example, whether 'junk foods' should be advertised on children's television. They can examine views from health experts, reports from food manufacturers and explore children's opinions on what influences their choice of food.

Table 7.4 Source of evidence used to support claims

Figures indicate the number of claims using each source of evidence out of the total number of claims made

E1= evidence provided; E2= evidence from personal experience; E1 & E2= both sources used in one argument

	Activity	**Gerbils**			**Bats**			**Cups**			**Marbles**		
Row	**Source**	**E1**	**E2**	**E1& E2**	**E1**	**E2**	**E1& E2**	**E1**	**E2**	**E1 & E2**	**E1**	**E2**	**E1 & E2**
1	**St Anne's Group 1**	6/6 **100%**	0	0	8/21 **38%**	13/21 **62%**	0	1/3 **33%**	0	2/3 **67%**	8/17 **47%**	9/17 **53%**	0
2	**St Anne's Group 2**	1/8 **13%**	6/8 **75%**	1/8 **13%**	3/9 **33%**	6/9 **67%**	0	2/9 **22%**	7/9 **78%**	0	5/6 **83%**	1/6 **17%**	0
3	**Castle Hill Group**	4/8 **50%**	2/8 **25%**	2/8 **25%**	7/13 **54%**	6/13 **46%**	0/13	2/11 **18%**	7/11 **64%**	2/11 **18%**	11/21 **52%**	10/21 **48%**	0
4	**Woodstreet Junior Group 1**	10/17 **59%**	6/17 **35%**	1/17 **6%**	N/A	N/A	N/A	1/5 **20%**	2/5 **40%**	2/5 **40%**	4/9 **44%**	5/9 **56%**	0
5	**Woodstreet Junior Group 2**	5/6 **83%**	1/6 **17%**	0	1/2 **50%**	1/2 **50%**	0	3/41 **7%**	34/41 **83%**	4/41 **10%**	1/1 **100%**	0	0

(N/A= not applicable as no arguments were constructed during the discussion)

These interpretations about the source of evidence used in the decision-making activities again suggest that there are complex effects from both the task and the group, that have a bearing on the results.

It has been argued that another important skill in decision-making is the consideration of alternative choices (Mitchell 2001); the next section presents the findings that show the number of alternative choices the different groups explore.

7.6 Results of the analysis of the number of alternative choices explored by the groups

Exploring alternative choices and considering both positive and negative issues of the possible choices have been identified as good practice in the argumentation process because in order to develop a strong argument, a wide range of evidence needs to be examined and other arguments need to be refuted (Osborne et al. 2001).

The activities were chosen to provide opportunities for discussion on a range of alternatives. In the Gerbils there were advantages and disadvantages to be considered for each home; similarly, in the Cups there were also advantages and disadvantages in using each cup. A strong argument would consider why a home or cup was an unsuitable choice as well as the reasons why a particular home or cup was a suitable choice. As explained in chapter 5, the situation was different in the Bats and the Marbles as the children were not presented with a limited choice but had to suggest their own alternatives, and they could introduce other alternatives during their discussions. In the Marbles the children could put forward any number of explanations to account for the anomalies in the given evidence.

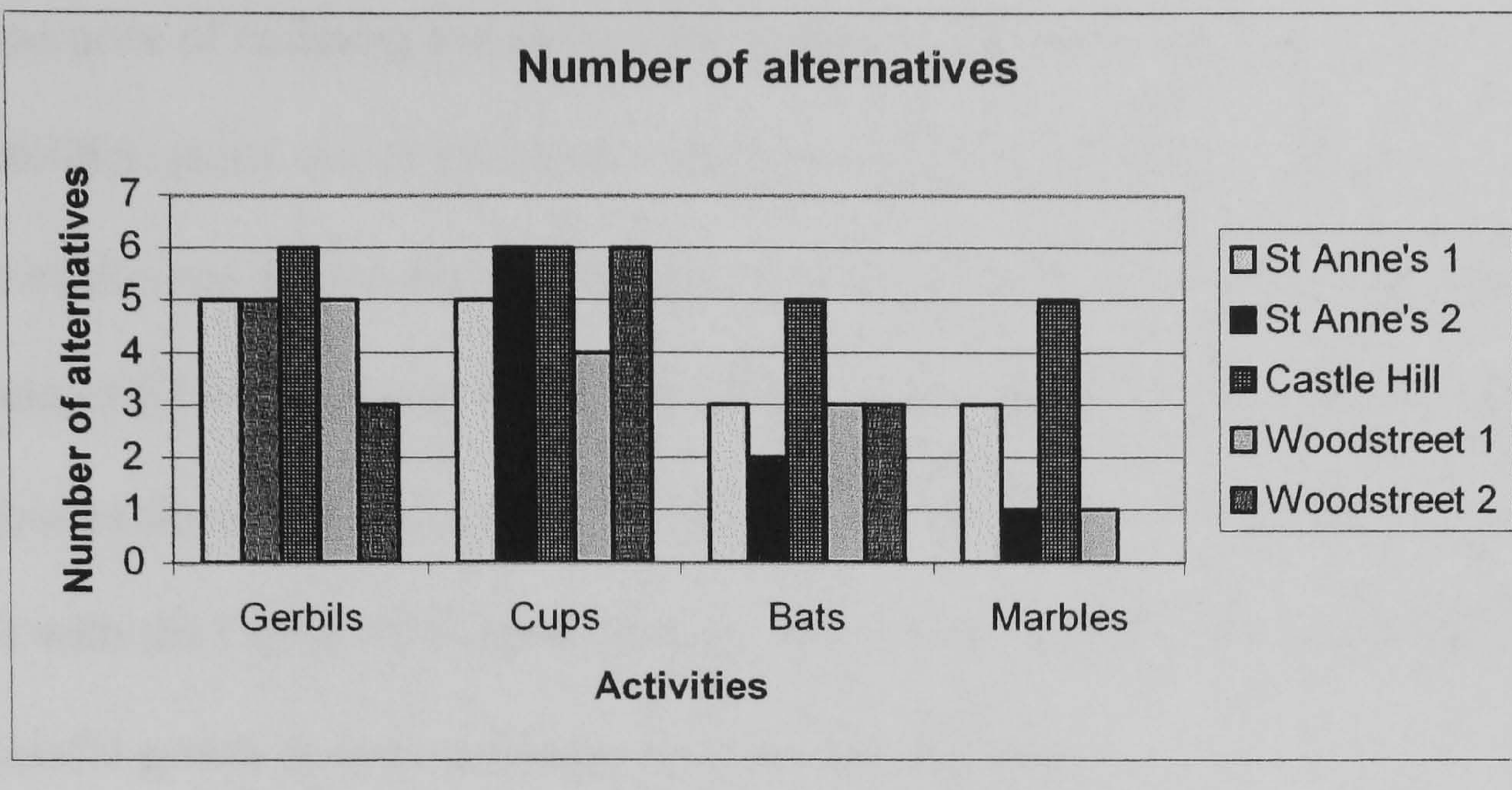
The data show that whilst some groups considered a range of alternatives, some groups were limited in the alternative choices they explored. In Table 7.5, the number of alternatives considered by each group of children is presented. As explained in chapter 6, a numerical score has been devised to facilitate comparison of a group in the four activities. As the table indicates, the highest score, when all alternative choices for the Gerbils and Cups are explored, is 12; the score for the other two activities has no limits as in the Bats and Marbles the children have to make their own suggestions.

Table 7.5 The number of alternatives explored by each group

	Activity	Gerbils: 6 possible alternatives	Cups: 6 possible alternatives	Bats: Group's own suggestions	Marbles: Group's own suggestions	Total Score
Row 1	St Anne's Group 1	5	5	3	3	**16**
Row 2	St Anne's Group 2	5	6	2	1	**14**
Row 3	Castle Hill Group	6	6	5	5	**22**
Row 4	Woodstreet Junior Group 1	5	4	3	1	**13**
Row 5	Woodstreet Junior Group 2	3	6	3	0	**12**

Row 3 shows that in every activity the Castle Hill Group considered a higher number of alternatives (score: 22) than the other groups. However, although the other groups considered fewer alternatives, the difference between the scores of St Anne's Groups 1 and 2 and Woodstreet Junior Group 1 is small (scores 16, 14 and 15 respectively). Woodstreet Junior Group 2 considered the least number of alternatives (score: 12).

Chart 3: The number of alternatives explored by each group



The results also show that the Castle Hill Group explored a wider range of alternative choices than the other groups in each individual activity, except for the Cups where their score was the same as St Anne's Group 1. They considered all the possible choices in both the Gerbils and the Cups and they put forward the greatest number of possible alternatives in the Bats and Marbles. In chapter 3, it was established that, in order to think and reason scientifically, people should be able to analyse information; the Castle Hill Group took time to consider alternative plans of action and they worked through the consequences of their decisions. The data would suggest that the children in the Castle Hill Group adopted scientific reasoning in all four of the decision-making activities because they did explore alternative choices, they evaluated the merits of these choices and made decisions based on the evidence available.

It is clear from the findings that the other groups of children have not developed the habit of systematic exploration of ideas when considering evidence in decision-making activities.

7.7 Summary of the groups' use of evidence

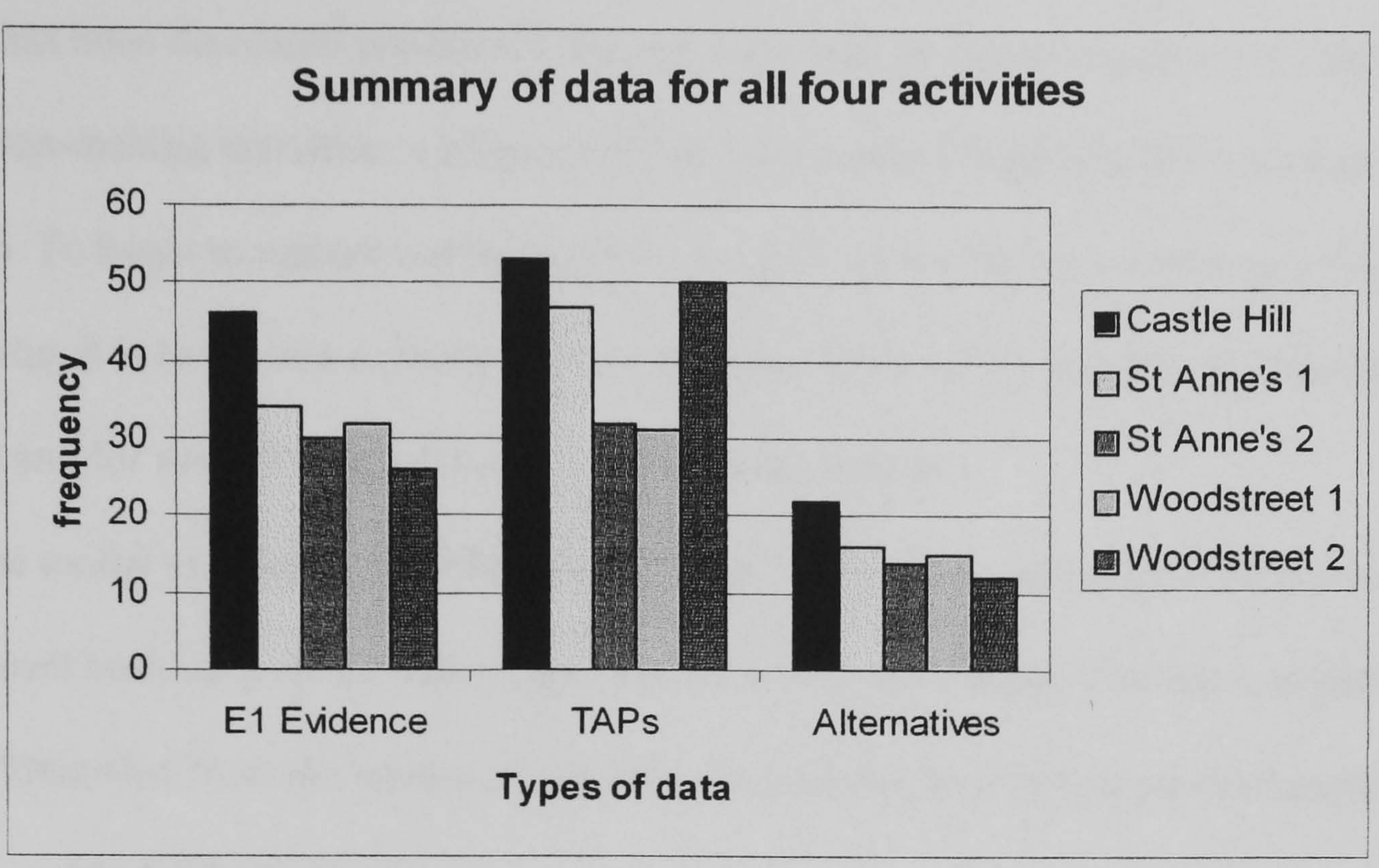
The purpose of collating the data in the coding schemes is to create a picture of the way the children made use of evidence in decision-making activities. To see this picture more easily, the data examined thus far, is summarised in Table 7.6. The table gives the amount of E1 evidence explored, the number of TAPs and the number of alternative choices explored totalled for all four activities. The data has been presented in order of merit with the Castle Hill Group first because this group has been identified as the most successful group in demonstrating skills of argumentation.

Table 7.6 Summary of data for all four activities

Row	Group	Total E1 evidence explored	Total number of TAPs	Score for alternative choices explored
1	Castle Hill Group	46	53	22
2	St Anne's Group 1	34	47	16
3	St Anne's Group 2	30	32	14
4	Woodstreet Junior Group 1	32	31	15
5	Woodstreet Junior Group 2	26	50	12

From these strands of the analysis, the results suggest that the nature of the group is a key factor in the overall differences shown by the groups in the way evidence is used. It is clear from the data that children demonstrate different skills of using evidence in decision-making activities as some explore more evidence and alternative choices than others and some make more claims supported by evidence. The chart below presents these data to illustrate patterns in the data.

Chart 4: Summary of all data for all four activities



Clearly, the chart shows that children, aged ten to eleven years old, have different skills in the use of evidence. As has been established, the Castle Hill Group had the most sophisticated approach to using evidence and the chart shows they have the highest score in all three aspects of the analysis discussed. The approaches adopted by St Anne's Groups 2 and Woodstreet Junior Group 1 were very similar. The Woodstreet Junior Group 2 explored the least amount of evidence and explored a limited range of alternative choices. The high number of TAPs put forward by this group has already been discussed in section 7.5.

The chart suggests that there is a link between the amount of E1 evidence explored and the number of alternatives considered as the distribution for the groups is in the same order. There are two possible explanations for this link. One, if more of the E1 evidence was explored than perhaps more alternatives choices would be considered; two, if all alternative choices were discussed then more E1 evidence would be used to make the final decision. The findings suggest the former explanation as in the Bats and Marbles, there is no limit to the number of options the children can consider. They had to put forward their own ideas. So it appears that the more E1 evidence explored by the children, the greater the range of alternative choices was considered.

It has been discussed previously that the way children interpret and use evidence in decision-making activities is affected by both the nature of task and the nature of the group. To begin to understand the way the groups used evidence to come to a final decision, it is important to study the way arguments are developed for the final choice made and for the rejection of the other alternative choices.

The model argument, described in section 6.5.1, gives an indication of the overall argument built up over the discussion. The next section explains how these arguments were identified from the transcripts and the findings for each group are discussed.

7.8 Model Arguments

The aim of the analysis of the model arguments was to show how the argument for the final decisions was built up during the discussion. The individual arguments made by the children, identified in section 7.5, contribute to the final decisions but the analysis of the model arguments concerned the structure of the overall argument of the group.

To identify the structure of overall arguments, first the substantive claims were identified. These claims were, for example, the final choice of a home for a gerbil or which cup to take on a picnic. In identifying these substantive claims, the number of alternative choices considered by a group, discussed in section 7.6, was verified as the arguments for and against the alternative choices were identified during the analysis.

The following section illustrates the method used for identifying the structure of the overall argument in St Anne's Group 1's decision. For this illustration the Gerbils was chosen but the modelling of arguments was applied to all four activities.

7.8.1 The structure of group arguments

The children in St Anne's Group 1 chose Home 2 to house the gerbils and the evidence used to justify this choice was:

- there was more room in Home 2;
- the home can be extended;
- there are more things in Home 2;
- there are different rooms for the gerbil to use.

These pieces of evidence are termed 'data' in Toulmin's analysis of the argument structure and warrants explain why the data support and legitimise the claim (Toulmin 1958). In the discussion, the warrants made explicit by the children were:

- more room means the gerbil can run around more;
- if the gerbil grows the home can be extended to accommodate it;
- if it had babies, the gerbil could put them in different rooms.

Thus, in this example, there are four items of data to support the claim and three warrants to give authority to the claim. The data and warrants for each activity have been identified for the final choice made by each group and these data are given in Table 7.7.

Table 7. 7 Structure of arguments for the final decisions

Group	Activity	Final choice	Data	Warrants
St Anne's Group 1	Gerbil	For Home 2	4	3
	Cups	For thick cup	3	1
	Bats	Tranquillise and catch bats in a net	4	1
	Marbles	Rebecca and Hari had a steeper slope for one tube	1	1
St Anne's Group 2	Gerbil	For home 1*	1	1
	Cups	For thick cup*	4	1
	Bats	Trap and remove bats	1	1
	Marbles	No conclusion drawn		
Castle Hill	Gerbil	For home 3	6	4
	Cups	For thick cup	9	0
	Bats	Seal the ceiling	3	2
	Marbles	Rebecca and Hari did not do a fair test	3	1
Woodstreet Junior Group 1	Gerbil	For home 2	10	6
	Cups	For thick cup*	4	3
	Bats	Get someone to remove bats	1	0
	Marbles	Rebecca and Hari did not work together properly	5	1
Woodstreet Junior Group 2	Gerbil	For home 2	4	1
	Cups	For thick cup*	8	3
	Bats	Trap and release bats	1	0
	Marbles	No conclusion drawn		

Note: The asterix indicates when one child in the group made an alternative choice.

7.8.2 The value of model arguments

The analysis of the model argument was designed to demonstrate the different approaches children take when using evidence to make a decision. However, as is now explained, the data provided a limited amount of useful information to show the different approaches to decision-making activities.

All the previous data analysis techniques have shown the Castle Hill Group to have more advanced argumentation skills than the other groups. The data has also indicated the limited argumentation skills of the Woodstreet Junior Group 2. However, the data in Table 7.7 does not support these findings; the use of data and warrants in an argument is considered to be an indication of a good argument (Osborne et al. 2001), and yet the Castle Hill Group demonstrated an inconsistent approach to the construction of well-supported group arguments. Conversely, the Woodstreet Junior Group 2 has provided more data and warrants for their arguments than, for example, St Anne's Group 2. This inconsistency in the findings suggests that either the previous data analysis is less reliable, or that the TAP analysis for the overall argument of the groups is not a useful technique in this situation. Observations of the groups would suggest that the latter is more likely.

Nevertheless, the data raise an important point for consideration, as it would appear that all the groups make more references to data and warrants in the Gerbils and the Cups. This finding suggests that the children constructed stronger arguments where there are limited choices given, i.e. the decision is forced by limited options. The data also suggest that children find it harder to construct well-supported arguments when the decision is more open-ended as, for example, in the Bats and the Marbles. So, if teachers want to develop children's skills in argumentation, it may be that children would find it easier to start constructing arguments in activities offering specific alternatives. Such activities need to engage the children in opposition and encourage them to provide counter-arguments so that the group interacts and works collaboratively together.

Another coding scheme developed to show how the groups approached the whole argumentation process is the discussion map, as described in section 6.6.2. The maps identify the patterns of the argumentation so that the way the groups of children worked together, and how their methods influenced the way evidence was used by the group, can be understood.

7.9 The pattern of the argumentation

As explained in chapter 6, discussion maps were designed to demonstrate the approach to argumentation taken by each group. These maps show, for example, whether a group discussed the evidence before decisions were made, or whether they put forward arguments and then debated the issues that arose. The formation of these maps led to levels of argumentation being established, which can be used to assess the patterns of argumentation of the groups.

Maps were constructed for each discussion for all five groups. The maps indicated, as explained in section 6.7, that the argumentation patterns shown by the children were at four different levels. Level 1 is the simplest form of argumentation, where there is discussion but evidence is not used to justify arguments, and the highest level, Level 4C indicates sustained argumentation involving discussion, review of evidence and the refinement or development of new arguments.

The discussion maps, set out in the following sections, have been selected to illustrate how the four different levels of argumentation are identified in the data. In some cases, where the argumentation pattern is the same throughout the discussion, the whole map is shown. Where the pattern changes within the discussion, only the relevant part of the map is included. As explained in chapter 6, the maps detail information about what the children are talking about in each episode and which children are involved in the discussions. Although nearly all four levels appear in all the activities, different activities have been selected to exemplify the four levels of argumentation. Level 1 is the simplest approach as the following example illustrates.

Argumentation Level 1

Example 1: Marbles

The characteristic of argumentation at Level 1 is that evidence is discussed but few or no arguments are put forward. Figure 7.1 shows the map for the Woodstreet Junior Group 2 for the marbles activity. The children read out the accounts of the marbles investigation and then discussed the different results recorded in these accounts. Although the children recognised the anomaly in the accounts of the marbles investigation, i.e. that Rebecca's conclusion did not correspond to her results (see line 98 and lines 105-106), the group did not put forward claims, justified or unjustified, as to why this was the case. They did not interrogate the evidence, or seek to justify why Hari and Rebecca's results were the same, but that their conclusions were different.

Jason made the only justified claim (see line 105), when he put forward his argument that Rebecca's conclusion was wrong because it did not correspond to her results. The discussion that followed did not reflect on why Rebecca had drawn the incorrect conclusion. The children did not come to any decision about what had happened and the discussion just came to a halt.

Figure 7.1 Discussion map, Level 1

Marbles Activity: Woodstreet Junior Group 2 **Children: Sharon (S), Jason (J), Elijah (E) and Chantal (C)**			
1 **Lines**	**2** **Episode**	**3** **Notes and source of evidence used** **C=claim, D=data appealed to**	**4** **Children**
27-39	**Clarification**	How do we know which is fastest?	S
40-46	**Review**	Children read the sheets. They pick up the tubes and run their fingers down the tubes.	All 4
47-53	**Discussion**	Talk about how the glue tube is fastest. Talk about that the results for the children are different.	J, E, S
54-57	**Clarification**	Can they use a marble to test the results?	E
58-60	**Review**	Reading conclusions for Hari and Rebecca.	S
61-65	**Discussion**	Making claims that the glue tube would be fastest. A prompt given by the researcher for the children to look at all the sheets.	S, J
66-97	**Review**	Read out Winston and Katy's sheet. Rebecca's sheet. Hari's sheet.	J & C E, S
98	**Clarification**	Jason brings Rebecca's sheet to JFM to check – her results do not agree with her conclusion.	J
99-101	**Review**	Continue to read Hari's sheet.	S
102-104	**Discussion**	Making claims for the glue tube.	J, S,C
105-106	**Argument 1**	C= Rebecca's got it wrong. D= It says the marble rolls down the glue tube fastest, but their results show that the bubble wrap is fastest.	J
107-135	**Discussion**	Talk about which tube is fastest.	All 4
136	**Finalising the activity**	It might go all different places, like over here and there but on this one (glue tube) it will go straight down. Even though it's got little bumps, it might jump over some. 'I rest my case!' 'I rest my case!'	J C S

Argumentation Level 2

Example 2: Cups

At Level 2, a series of arguments are made; however, there is no engagement with each other's ideas, no challenges made when opposing arguments are put forward and no negotiation to resolve any differences in opinion.

The discussion map, in Figure 7.2, is from the Cups for the Woodstreet Junior Group 1. At the beginning of the activity the children put forward a series of justified claims about their choice of cup to take on the picnic, but there had been no prior discussion about the E1 evidence before these claims were made. The children did not agree on the cup to take; Amy said she would take the thin plastic cup whilst the other three children chose the thick plastic cup. However, only Che made some attempt to engage in any debate on the issue (see line 18). She challenged Amy's choice (lines 14-15), but Amy did not respond. Patrick then made his claim regardless of Che's intervention.

The overall pattern of the argumentation indicates that the group did not interact with each other, but merely took it in turns to speak. Without an understanding of how a group can work collaboratively together, there appears to be no perceived need for negotiation and the group worked as individuals. If, as argued in chapter 4, group work is an important feature of how children can learn, then it is important that children are taught how to work together on a task as a group.

Figure 7.2 Discussion map, Level 2

Cups: Woodstreet Junior Group 1 Children: Che (C), Amy (A), Jillese (J) and Patrick (P)			
Time: 1minute			
1 Lines	**2 Episode**	**3 Notes and source of evidence used C=claim, D=data appealed to**	**4 Children**
	Review	Children read the sheets as they gave an explanation of the how the results were obtained.	
10-11	**Argument 1**	C= 'I thought I'd take this one (thick plastic) ...' D= 'because this one (thin) will get squashed + this one will (glass) smash.'	C
12-13	**Argument 2**	C= 'I thought this one (thin plastic) ...' D= 'because after you have finished you can put it in the bin.'	A
14-15	**Argument 3**	D= 'This one (thin) can get squashed.' C= 'You won't be able to use it (thin plastic) again.'	C
16-17	**Argument 4**	C= 'I'd use this one (thick plastic) ...' D= 'because all you have to do ... to use it again is wash it; this one (thin) just gets thrown in the bin.'	J
18	**Discussion**	Talk about how the thin cup is a waste of money.	C
19-22	**Argument 5**	C= 'I'd go for this one (thick plastic).' D= 'This one (thin) gets squashed, that one (glass) can get smashed; This one (thick) is strong, flexible, and it can't snap or nothing.'	P
	Finalising the activity	Silence.	

Argumentation Level 3

Example 3: Cups

At Level 3A arguments are made, discussed and then another argument is considered. These arguments may be still be unrelated, as in Level 2, but at Level 3A the arguments are discussed even though there is no engagement in debate about the merits of the different claims made. Discussion may involve long stories that, although triggered by the arguments being considered, include some irrelevant details.

The following map, shown in figure 7.3, is from the Cups for Woodstreet Junior Group 2. At the beginning, the discussion was at different levels so only an extract of the discussion map is given. The extract starts when the argumentation is at Level 3A, after Elijah has explained why he chose the thin plastic cup. His claim led to some discussion about the suitability of the cups for use outdoors and how the glass cup could easily break.

Figure 7.3 Extract from a discussion map, Level 3

Cups: Woodstreet Junior Group 2 **Children C= Chantal; E= Elijah; J= Jason and S= Sharon**			
1 **Lines**	**2** **Episode**	**3** **Notes and source of evidence used** **C=claim, D=data appealed to**	**4** **Children**
83-90	**Discussion**	Talk about what happens if you drop cups, Chantal's story about her family, and who uses which type of cup.	J, S,C
91-94	**Argument 9**	C= 'I think this one (thick) would be the right cup for her (baby sister) ...' D= 'because if she falls glass would cut, this one (thin) would crush and this one (thick) would squash and bounce again.'	C
95-97	**Argument 10**	D= 'My brother and sister climb on the table ... they always get the glass and smash the glass.' C= 'So that's why I think this (thick plastic)'.	J
98-107	**Discussion**	Sharon's story about her grandmother's house and the cups they use at Christmas, including descriptions of the house and staircase.	S
108	**Argument 11**	D= 'My uncle smashed a glass on floor.' C= 'So that's why these cups (thick) plastic are good for him.	S
109-121	**Discussion**	Stories about dropping cups, babies with glass, where glass cups should be kept.	S, J, C
122-123	**Argument 12**	C= 'I baby picks up the glass ...you would take glass from a baby ...' D= 'because it's not safe.'	S

A map for Level 3B is not included as it comprises a similar pattern to Level 3A; it includes arguments with discussion that do concern the arguments put forward. However, the arguments made are the same and just reinforce claims made previously, and the discussion does not include challenges to claims made or counter-arguments.

Argument Level 4

Example 4: Bats

Again, just one map is included for Level 4 as all three types comprise discussion that leads to the formation and evaluation of arguments. At Level 4C, the discussion is the most complex as there is sustained argumentation.

The map, shown in Figure 7.4, is from the Bats for the Castle Hill Group and is an example of a discussion at Level 4C. The argumentation was 'sustained' as the group referred back to evidence when considering their original plans, and new ideas arose as a result of their discussions. The whole map has been included to show how this group follow an iterative process where arguments were made, evidence for the claims was reviewed, and alternative arguments were formed in the light of new evidence or the outcome of the discussions.

As more evidence was read, the children discussed its implications for their plans, as can be seen in Argument 3. Here, the evidence provided in the cards was used to build up a case to reject Simon's plan to sweep the bats out with brooms (see line 145) and support Joanne's idea of building a false ceiling beneath the roof.

There are also episodes of clarification where the children checked, for example, the meanings of terms, clarified the task and the decision to be made. The group worked collaboratively together; six of the ten episodes of discussion involved all of the group and there are only two occasions when the discussion only involved two children.

Figure 7.4 Discussion map, Level 4

Bats: Castle Hill School **Children: Joanne (J), Cicley (C), Simon (S) and Alex (A)**			
1 **Lines**	**2** **Episode**	**3** **Notes and source of evidence used** **C= claim, D= data appealed to**	**4** **Children**
66-79	**Clarification**	What is roosting? Can they look at whether the fact is true or false?	All 4
80- 94	**Review**	Reading *BAT FACT?* card which states that it's against the law to kill a bat.	
95-96	**Argument 1**	D= 'You can be fined up to £2000 for killing or injuring a bat.' C= 'Obviously we can't use the brooms.'	A & C
97-103	**Argument 2**	C= 'No (you can't just chase them away.' D= 'You might hit them by accident.'	J
104	**Clarification**	Can they use biros to write with?	C
105-110	**Discussion**	Talk about Simon's plan.	J, S+A
111-113	**Argument 3**	D= 'Bats are delicate animals.' C= 'Simon's plan wouldn't work.'	A
114-116	**Review**	Reading *BAT FACT?* card that states that bats are endangered.	C
117-131	**Discussion**	Talk about Simon's plan.	All 4
132-142	**Argument 4**	C= 'I don't think it's a good idea to move the bats …' D= 'because it says here … bats are endangered.'	C
143-144	**Argument 5**	D= 'You cannot disturb roosting bats.' C= 'We cannot move the bats.'	J
145-211	**Discussion**	Reject Simon's idea; Alex's idea about covering the books.	All 4
212-215	**Argument 6**	D= 'Bats carry diseases.' C= 'So you would have to have cleaning equipment.'	J
216-217	**Review**	Reading *BAT FACT?* card that states that bats droppings are a health hazard.	J
220-222	**Argument 7**	D= 'If bats droppings are dry.' C= 'You can sweep bats droppings up.'	C
224-226	**Review**	Reading *BAT FACT?* card which tells them that bats urine damages wooden floors.	C
227-233	**Discussion**	Talk about the floor.	All 4
234-235	**Argument 8**	C= We could put plastic sheet over the library.' D= 'So it (urine) doesn't go on the floor.'	S
236-240	**Discussion**	Talk about how a sheet wouldn't look good. ***Continued overleaf***	J+C

1 Lines	2 Episode	3 Notes and source of evidence used C= claim, D= data appealed to	4 Children
241	**Argument 9**	C= 'It's better covering the ceiling\...' D= 'because it means that just below the ceiling.'	C
242-296	**Discussion**	Talk about the effects of sealing up the ceiling.	J,C+A
297-299	**Review**	Reading *BAT FACT?* card which tells them that bats prefer modern houses.	J
300-307	**Clarification**	Is the library old? Do they want the wooden floor? Does it matter if it gets a bit ugly?	S+J C A
308-311	**Discussion**	Simon makes a joke about stools and bats' droppings.	S
312	**Argument 10**	C= 'Bats droppings have a use.' D= 'Most droppings do.'	A
316-319	**Clarification**	What is the use of bats droppings?	C+J
320-334	**Discussion**	Simon's idea is silly.	All 4
335-336	**Argument 11**	C= 'Have a false ceiling.' D= 'So the bats' droppings won't come through.'	C
337-341	**Discussion**	What is Simon's new idea?	J+S
342-349	**Argument 12**	C= Send off droppings for research. D= because the droppings are made out of skeletons.	S
350	**Review**	Reading *BAT FACT?* card which states that all bats drink blood.	J
351-372	**Discussion**	All bats don't drink blood. About Argument 11. About sealing the roof.	All 4
373-376	**Argument 13**	C= 'We should seal the roof ...' D= 'because it's cheaper.'	A
377-388	**Discussion**	Who agrees with sealing the ceiling?	All 4
389-390	**Finalising the activity**	'I think we're OK ...' 'We've finished!'	J C

The maps in figures 7.1 to 7.4 illustrate the different approaches to the decision-making activities. The next section explores the range of levels of argumentation, identified using the maps that were reached by the five groups in the different activities.

7.10 The levels of argumentation

This schema of analysis enabled the performance of argumentation to be identified for the different groups in each activity. Occurrences of the different levels identified in each map are presented in Table 7.8 where the incident of each level in a discussion is represented with a tick. As can be seen from the table, some maps indicated only one level of argumentation in a discussion, but most discussions included incidences of different levels throughout.

The analysis indicates the following features:

- the activities developed in this study are within the capabilities of children aged ten to eleven years old as two groups' argumentation skills were at Level 4C in at least two activities;
- children, aged ten to eleven years old, show a range of abilities in the way they engage in group discussion;
- the Castle Hill Group may not have been fully challenged by the activities as it reached the highest level in all four activities, so it is possible that the range of abilities of this age group may be even wider than is indicated by the results;
- the Woodstreet Junior Group 2 has the lowest levels of argumentation skills and this group has also been identified as the weakest group in the way they use evidence;
- the inconsistency in argumentation shown by some of the groups is not due to the nature of the activity as the Castle Hill Group reaches the highest potential level in all four activities;
- the results reinforce a previous finding that the format of the evidence is not a causal factor in the different levels of argumentation reached by the group.

Table 7.8 Levels of argumentation for sequences of the discussions

St Anne's Group 1	**1**	**2**	**3A**	**3B**	**4A**	**4B**	**4C**
Gerbils				√		√	
Cups							√
Bats		√			√	√√	
Marbles		√				√√√	√
St Anne's Group 2	**1**	**2**	**3A**	**3B**	**4A**	**4B**	**4C**
Gerbils	√	√			√		
Cups					√	√	
Bats	√	√			√	√	
Marbles				√	√		
Castle Hill Group	**1**	**2**	**3A**	**3B**	**4A**	**4B**	**4C**
Gerbils							√
Cups							√
Bats							√
Marbles							√
Woodstreet Junior Group 1	**1**	**2**	**3A**	**3B**	**4A**	**4B**	**4C**
Gerbils			√	√		√	
Cups		√					
Bats	√						
Marbles		√		√			
Woodstreet Junior Group 2	**1**	**2**	**3A**	**3B**	**4A**	**4B**	**4C**
Gerbils		√				√	
Cups		√√√	√√√√√	√		√	
Bats	√		√	√			
Marbles	√			√			

7.10.1 Children's development in argumentation skills

The groups of children were given four different decision-making activities over a period of seven months and yet the data do not suggest any overall improvement in the children's skills over time. This finding would suggest that the activities selected give an accurate picture of children's argumentation skills and there has been no 'Hawthorne effect'. The Hawthorne effect is where the mere act of showing people you are concerned about them leads to an improvement in performance (Pugh and Hickson 1964).

The lack of improvement also suggests that giving children the opportunity to argue, and to use evidence to make decisions does not ensure that their argumentation skills will necessarily develop. This research, therefore, leads to the conclusion that teachers will need to teach the children how to work in a group, and teach them how to review and evaluate evidence, because they do not seem to be developing these skills just by being given the opportunity to use them. Yet, as the Castle Hill Group show, children are indeed capable of sustained argumentation where evidence is reviewed and its impact on their decision is understood. If teachers become aware of the need to make these skills part of their teaching objectives, then perhaps we can begin to develop all children's argumentation skills in the future.

7.10.2 The need for teacher intervention

To develop thinking skills, teachers need to give children opportunities to make their thought processes explicit (Mercer 2000). Mercer suggests that they can do this by:

> demonstrating to children the use of problem solving strategies, explaining to children the meaning and purpose of classroom activities, and using their interactions with children as opportunities for encouraging children to make explicit their own thought processes.
>
> (Mercer 2000:160)

Teachers need to develop children's group work skills beyond the level of 'taking it in turns' to speak. Listening to each other is not merely a matter of being quiet when another person speaks; listening requires a response to what is being said. The Castle Hill Group listened to each other, they disagreed with each other and asked one another to justify their claims. The consistency in performance of the Castle Hill Group suggests that they have developed some sort of framework for the argumentation process, and know how to work together collaboratively.

In contrast, the inconsistent performance shown by other groups suggests that although they were capable of high levels of argumentation, they had no framework for the argumentation process and their performance was erratic. There was no evidence of 'collective thinking' (Mercer 2000) as there were few instances of children asking questions of each other to find out how a claim could be justified.

7.10.3 The context of the activities

The data do not suggest that there is any differences between the ways the groups perform in argumentation when presented with evidence in different formats. The data show no pattern between the results for the Gerbils and the Bats, where evidence was presented in pictures and information, nor between the results for the Cups and the Marbles where evidence was presented in tables of figures. This finding would indicate that teachers could use a variety of contexts to develop children's argumentation skills.

An activity designed to develop children's argumentation skills would require that children could understand the meaning of the evidence they have been given, they could appreciate the nature of the problem they are discussing, that the evidence provided is not conclusive and that there would be a plurality of views generated by the discussion.

So far, the findings discussed in this chapter have concerned how children reason and use evidence when working in a group. The second strand of the analysis concerns how the children reason and make use of evidence when working on their own, and the next section explores the findings from the analysis of the individual interviews with the children.

7.11 Key findings of how children use evidence when working as individuals

In seeking to find out whether children can use evidence to support their claims when working as an individual, there are two aspects to consider. First, if a child behaves differently in the two situations, for example, a child might not justify their choices when working with peers in the group work, but will do so when working with an adult in the interview. Second, a child might be capable of selecting evidence to justify a choice, but will only do so when prompted. As will be discussed more fully in the next chapter, some children do ask others to justify their claims and give reasons for their choices. However, as this research involved groups of children working autonomously, there were some groups of children where no one asked for reasons why a choice had been made. Therefore, it was not possible to assess whether children could justify a claim when prompted as no prompts were made in the discussions.

The main aim of the interviews was to find out whether children would justify the decision they had just made with their group or whether they needed prompting to do so. The next section explores the children's individual responses when interviewed after the activities.

7.11.1 Responses at interview

The questions put to the children in the interviews were designed to elicit whether they would:

- justify their choice and explain why the alternative choices were rejected in the Gerbils and the Cups;

- explain why their original plan, about what to do with the bats, had been maintained or rejected and what decision had been reached;
- select which tube they thought the marble would roll down faster and give an explanation for the anomalous results reported in the accounts of the investigation (Hari and Rebecca's accounts).

The coding scheme, described in chapter 6, indicates whether a child needed prompting to justify the decisions or not. For example, Joanne who required no prompts to justify her decisions is coded as C and Osei, who required prompts to justify his choice and to consider alternative choices, code B. Code A indicates the child required constant prompts to justify the claims made. The findings of this analysis for all the children are given in Table 7.9.

The data indicate that, when questioned on their own, *all* children are capable of justifying the choices made. However, some children will do this without prompting, whilst others need to be challenged and questioned further to elicit the reasons why they made the choices.

The children in the Castle Hill Group consistently gave full answers to the questions and justified their choices without prompting; this is the group to be considered the most effective at using evidence. They demonstrated the skills required, as discussed in chapter 2, for critical reasoning. Evidence of their reasoning is found in the way the group highlighted discrepancies in each other's claims, and the way group members were able to change their minds in the light of the arguments put forward.

All the children in Woodstreet Junior Group 2 had to be prompted to give justification for their choices and to explain why they had rejected alternative choices; this is the group that has been identified as the least effective in using evidence. As discussed previously, these children do not think collectively, and have no expectation that their claims might be questioned or that they should question opposing claims. Children in this group made their decisions and were not influenced by the arguments of other members of the group.

Table 7.9 Data from the interviews for all activities

Children	Gerbils	Bats	Cups	Marbles
St Anne's Group 1				
Luke	B	B	B	A
Naveed	N/A	No change	C	B
Osei	B	B	C	B
Sheerah	B	B	B	A
St Anne's Group 2				
Alicia	B	A	C	A
Daniel	C	A	B	B
Heidi	B	B	B	A
Junior	C	A	C	A
Castle Hill				
Alex	C	C	C	C
Cicely	C	C	C	C
Joanne	C	C	C	C
Simon	C	B	C	C
Woodstreet Junior Group 1				
Amy	B	No change	B	B
Che	C	No change	B	C
Jillese	B	No change	B	C
Patrick	B	No change	B	B
Woodstreet Junior Group 2				
Chantal	B	B	B	A
Elijah	A	A	B	A
Jason	B	B	B	B
Sharon	B	B	B	B
Key: A= needs constant prompts to provide justification for answers; B= needs some prompts to provide justification for answers; C= needs no prompts to provide justification for answers				

Note 1: N/A is when the recording of the interview failed and so no data is available.

Note 2: In the Bats some children had not changed their plan on reading the *BAT FACT?* cards and this is indicated in Table 7.9 as 'No change'.

7.11.2 Differences in behaviour between group work and individual work

The data indicate that some children behaved differently in the interview to the way they behaved in the group situation. For example, Sheerah, in St Anne's Group 1, made 22 claims supported by data in the discussion, the most justified claims of all the children, and yet she needed prompting to give reasons for her choices in all the interviews. Alex, in the Castle Hill Group, made only six justified claims in the discussions yet in the interviews he needed no prompting to justify his choices. Patrick and Jason, in Woodstreet Junior Group 1 and 2 respectively, each made only two claims supported by evidence in the group discussions, but in the interview both boys showed they were capable of providing the evidence when prompted. If these boys had worked with children who had questioned their ideas, then perhaps they would have been encouraged to review evidence more effectively in order to provide justification for their claims.

The data suggest that children who make a similar number of justified claims in a group discussion do not necessarily justify their answers in the interviews in the same way as each other. For example, some children who needed prompting in the interview to provide justification for every claim in the interview (Code A) did not necessarily need such prompting when working in a group comprising children and no adult. Likewise, some children that needed no prompting in the interviews (Code C) did not necessarily justify their claims in the group discussion.

It is not possible to be certain from this research whether the class teacher of each group would be a key factor in the way children respond in the interview and group situation. In other words, does the way a teacher intervenes in whole class and small group discussions affects the way children respond as an individual. For example, as Mortimer and Scott (2003) identified, teachers whose interventions are designed to check children's understanding, will ask children to clarify their ideas and expect them to be able to justify their claims. That is, could the role the teacher adopts in the classroom be a model for the way the children behave in the group? As will now be explored, the responses of the children from Castle Hill School suggest this could be the case.

7.11.3 Consistency in behaviour between group work and individual work

The children in the Castle Hill Group behaved in very similar ways to each other in the interview and they are coded C for fifteen of the sixteen interviews. This similarity within a group could indicate that children from the same class respond in the same way to an adult in the role of 'teacher'. Children, whose teacher has encouraged them to justify answers, or who models the way claims should be justified and challenges the children's unjustified claims, may well respond in the same way as the children in the Castle Hill Group. Conversely, children who have not been expected to justify their claims may well require prompts in order that they should do so. Yet, all these children *could* justify their claims when prompted and this poses the question:

> In a group discussion, if children were challenged by their peers in the way they were by the interviewer, would they all provide more justified claims?

Further research would be required to find out whether children, whose teachers do expect children to justify their ideas in the whole class situation, would expect group members to justify their claims when working without adult intervention.

Conclusion

A key implication of the findings reported in this chapter is that, if the Castle Hill Group's argumentation approach has been taught in science activities in school and the 'taking in turns' approach has also been taught to the other groups, then teaching can make a significant impact on group productivity and learning.

As the findings indicate that children, aged ten to eleven years olds *are* capable of good argumentation skills whereby they consider the merits of the possible choices and can justify the choice made, then these skills could be taught to children in primary schools. They could be made aware of what good argumentation skills are and be taught how they might use them in reaching their decisions. The skills used in good quality argumentation need to be made explicit and children need to be given the opportunity to practise these skills in a variety of contexts.

The performance of any group is limited by a number of different constraints. The children's abilities, their communication skills and their understanding of how to work within a team, all influence the level at which the group engages with the decision-making process. The key factor emerging from the data in this research, which affects the way young children engage in this process, is the way the group works together as a team. The findings show that children, who do work collaboratively, demonstrate more developed skills in argumentation than other groups. When children do engage in argumentation *as a group* then more evidence is discussed, more claims are justified and a wider range of alternative solutions is considered.

Summary

This chapter has presented the results derived from the different strands of the analytical framework. It has been concluded that the way the group works together has an important effect on the way children use evidence. It became clear that the roles the children adopt in group work have a considerable influence on how evidence is discussed and used in decision-making activities. The next chapter explains how the roles have been defined and what effects each role has on the children's discussions.

Chapter 8 The roles children play in group activities

8.0 Introduction

The last chapter explained how the data were analysed to show how groups of children argued and made use of evidence in decision-making activities. The chapter concluded by suggesting that a possible reason that some children argued more successfully and made better use of evidence is because they worked more collaboratively together. This chapter explores how the ways groups work together as a team affect the way children engage with the decision-making process.

How teams work together has been the focus of much research, particularly in the world of management theory. Here, the most important factor identified as crucial to the success of a team is the role adopted by each team member. Some of the roles adopted by the children observed in this research were very similar to the roles identified in team management literature. Consequently, parallels are drawn between the characteristics of the successful groups of children and successful adult teams in the world of management (Belbin 1981; Margerison and McCann 1990). Definitions have been devised to identify the roles children adopt when working in groups, and the framework developed to identify these roles is explained in this chapter. The characteristics of each role are described and are illustrated by examples from the transcripts.

In team management studies, it has been found that the most successful teams encompass a range of different roles; where there is an imbalance of roles, teams are less likely to be successful. The findings of this research indicate that the groups of children who worked together more effectively comprise a range of roles; in the groups where there was less argumentation and less effective use of evidence, the children had adopted similar roles to each other.

It is suggested that as management teams have benefited from analysing their roles and gaining insights about how roles affect the effectiveness of groups, so too, group work in schools could benefit from analysis to see which are the most successful combinations of role types. This chapter explores how the data from this research supports this recommendation.

8.1 Successful teams and successful groups

In order to understand what factors affected the way the groups of children worked together, the research draws upon two influential management studies that have examined how successful teams work together and how team performance can be improved. Management studies have looked at the way team members worked together to develop a picture of what a successful team looked like so that team building can be promoted in a company.

The key study referred to was the work of Meredith Belbin. Belbin (1981) in his seminal work, *Management Teams*, describes how teams work in order that team performance could be improved and, thereby, increase business success. He found that an understanding of team building was crucial to the successful growth and development of a business.

Margerison and McCann (1990), who also studied team management, suggested that there is a role central to the success of a team that links the team together; this role they termed the 'Linker'. A Linker ensures that the team cooperates and works together as a team. The research reported in this thesis has drawn upon these two management studies to suggest that the roles the children adopt within a group are also crucial to a group's success. However, before the roles children adopt are examined, what characterises a 'successful group' needs to be clarified.

8.2 The characteristics of the successful group

The success of a team must be judged in relation to the objectives of that team. As this research is about how children argue and use the evidence provided when making choices, judgements have been made as to what is considered as a 'good' use of evidence, and what are meant by good argumentation skills.

In the activities in this research, a successful group is characterised using criteria, drawn from Mitchell's (2001) list of parameters (see Section 6.1). These characteristics are that, in coming to a decision, the group:

- considers a wide range of the evidence made available to them
- makes claims supported by evidence
- considers a range of the possible choices
- explores both positive and negative issues of these choices
- discusses the arguments put forward rather than just listening to them
- may refine or reject previous arguments after discussion.

As discussed in chapter 7, the children in the Castle Hill group (Alex, Cicely, Joanne and Simon), were considered to be a successful group as they demonstrated the most sophisticated skills of argumentation of the five groups. The children in the Castle Hill group showed openness to other people's thoughts, as well as the capacity for constructing ideas together. The ability to express partially formed ideas and to think together is facilitated when the responsibility for the discussion is shared and anxiety is reduced (Pontecorvo and Giradet 1993). However, for children to think together successfully, they must work together successfully. Thus, it is important to understand what factors can facilitate groups of children working well together in the same way that successful business teams are created.

In studying the way these children worked together, it became clear that the behaviour of Joanne had a major influence in determining the way the group worked together. She demonstrated a strong sense of teamwork and organised the group so that all members took part in the discussion. It was this behaviour of Joanne, in particular, that suggested that parallels could be drawn between the behaviour of children and that of people in successful management teams.

The research into management teams is based on the behaviour of adults in business, so the roles identified in management teams were studied to see how relevant they are when working with children in primary schools.

8.3 Management teams

Belbin (1981) describes 'team roles' that show a pattern of behaviour in which one team member interacts with another in facilitating the progress of the team as a whole. In his study of teams from different organisations around the world, he identifies eight types of people as useful to have in a team (see Table 8.1) and he assigned typical features to each role. These types have become part of everyday language in organisations all over the world.

The typical features assigned to each role characterise the positive qualities and allowable weaknesses of each role. One of Belbin's key messages is that:

> Teams are a question of balance. What is needed are not well-balanced individuals but individuals who balance well with one another.
> (Belbin 1981: 75)

Belbin found that in a mixed team, where the members recognise the needs of the team in regards to team roles, there is always someone prepared to underpin any weakness in the team.

Table 8.1 Belbin's 'Useful people to have in teams'

Type	Typical features	Positive qualities	Allowable weaknesses
Company Worker	Conservative, dutiful, predictable	Organising ability, practical common sense, hard-working, self-discipline	Lack of flexibility, unresponsiveness to unproven ideas
Chairman	Calm, controlled, self-confident	A capacity for treating and welcoming all potential contributors on their merits and without prejudice. A strong sense of objectives	No more than ordinary in terms of intellect or creative ability
Shaper	Highly strung, dynamic, outgoing	Drive and a readiness to challenge inertia, ineffectiveness, complacency or self-deception	Proneness to provocation, irritation and impatience
Plant	Individualistic, serious-minded, unorthodox	Genius, imagination, intellect, knowledge	Up in the clouds, inclined to disregard practical details or protocol
Resource Investigator	Extroverted, enthusiastic, curious, communicative	A capacity for contacting new people and exploring anything new. An ability to respond to challenge	Liable to lose interest once the initial fascination has passed
Monitor-Evaluator	Sober, unemotional, prudent	Judgement, discretion, hard-headedness	Lacks inspiration or the ability to motivate others
Team Worker	Socially orientated, rather mild, sensitive	An ability to respond to people and to situations, and to promote team spirit	Indecisiveness at moments of crisis
Completer-Finisher	Painstaking, orderly, conscientious, anxious	A capacity for follow-through. Perfectionism	A tendency to worry about small things. A reluctance to 'let go'

(Belbin 1981: 74)

As has been described earlier, the role Joanne adopted was central to the group working together. She was the one who encouraged others to put forward their ideas so that more suggestions could be considered. She also demanded explanations from the group so that evidence had to be given to justify the different opinions. Margerison and McCann, like Belbin, find that high performing teams (HPTs) are well balanced with respect to the roles people play, but they observed teams that were 'beautifully balanced', but failed because there was 'no linking being done'; there was no cooperation or exchange of ideas. The Linker will be involved in, for example, communication, team development and participative decision making. If everyone in a team takes responsibility for linking the group process, then a network will be formed within the team, and so the team develops a sense of identity. Margerison and McCann found that the level of cooperation and *esprit de corps* is strong amongst HPTs, and people want to work to help each other.

Margerison and McCann believe that linking is a set of skills that all people can develop and thus, weak teams can be improved by training of the team members. So, as team building for adult groups can be improved by an understanding of how the team works together, then it is important to understand how groups of children work together. Thus, if the successful working of groups of children can be attributed to the roles children play then it is essential that these roles can be identified. We can then optimise our understanding of *how* groups of children work together in order that their performance in group work can be improved. However, the research into management teams is based on studying the behaviour of adults and the role definitions, developed by the management theorists, are not entirely relevant to identify the roles of children in primary school groups. Thus, a new set of roles has to be defined.

8.4 The analytical framework for role definition

Belbin defined his eight roles after observing successful teams in both an experimental situation and in the workplace. To define the roles observed in the children working in groups, indicators such as how they contributed to the discussion, how they related to other group members and responded to other points of view, were used for the initial analysis. The initial examination of the transcripts was also informed by Mercer's (1996) work on describing the quality of children's talk in collaborative activities (see section 6.4). Mercer identified different types of talk, and so the children's talk was examined, and the 'speech acts' (Do they ask others to say what they think? Who proposes what should be done?) and behaviour of each child was noted. This analysis of the spoken text helps define the content and function of the talk of each child so that a profile of the individual's contribution to the whole discussion can be built up. To build up a picture of the roles children adopt in group work, the transcripts were examined for patterns of behaviour, drawing on the idea of Mercer's 'speech acts'. For example, some children gave instructions to other group members; others challenged other member's ideas. Table 8.2 illustrates the type of speech acts identified in the transcripts of the Castle Hill Group.

Table 8.2 Behaviours of the Castle Hill Group

Child	Typical features of behaviour in discussions
Alex	Makes claims supported by data in two activities. Responds to others and poses questions to challenge claims. Responds to others and confirms points made. Makes no effort to persuade others of the merits of his ideas. Makes suggestions, but is often interrupted or ignored.
Cicely	Questions the researcher to check instructions for the task. Makes claims, supported by evidence, in all activities. Responds to others and poses questions to challenge claims. Pays attention to details. Follows the 'rules'. Brings the group's attention to E1 evidence.
Joanne	Questions the researcher to check instructions for the task. Manages the discussion by suggesting what the group should do. Asks the others for contributions. Makes claims, supported by evidence, in all activities. Explains why she changes her mind. Responds to others and poses questions to challenge claims. Agrees with a decision made by others. Brings the group's attention to E1 evidence.
Simon	Makes claims supported by evidence in three activities. Shows imagination. Sometimes asks others for contributions. Distracts the group with his silly behaviour. Is impatient to get the decision made. Pushes for a decision to be made. Makes a decision.

By examining the different speech acts demonstrated by the children from all groups, the role definitions began to emerge. First the behaviours were compared to Belbin's roles to see if his definitions drawn from teams of adults could be applied to groups of children.

8.5 Applying Belbin's roles to children's behaviour

On examining the transcripts for this group, it became clear that the children behaved in a consistent fashion and played a similar role in the four activities. A description of each child's behaviour illustrates how the similarities between children's behaviour in group work echoes those behaviours observed in adult teams.

8.5.1 Joanne

As previously stated, Joanne played a prominent role in organising the group, and took on a role that can be seen to have strong similarities with the role adopted by Belbin's 'Chairman' (See Table 8.1). The positive qualities identified in Belbin's definition of a Chairman are a capacity for treating and welcoming all potential contributors on their merits, and a strong sense of objectives. This is a strong feature of Joanne's behaviour, as the following examples illustrate:

> **Cups**
> Joanne started off the Cups by drawing in all members of the group:
>
> **Joanne**: Okay Alex, you say what you think first and then we'll go round.
>
> **Bats**
> In the Bats she started the discussion:
>
> **Joanne**: Shall we pick up one (a *BAT FACT?* Card) and all discuss it?

In the Gerbils, Simon was pressing for a decision with which Joanne disagreed. When Simon asked for a vote, Joanne suggested that they go round the group separately, and each tell her why they did not want Home 1. She wanted the group to reach a joint decision and demanded that each member of the group explained their reasoning. Joanne was always calm and self-confident, the typical features of Belbin's 'Chairman'.

8.5.2 Simon

Joanne was not the only child to show similarities to one of Belbin's roles. At times, Simon was deeply involved in the discussion but, at other times, he appeared to be completely distracted and 'off - task' within the same activity. He would gaze around the room, stand up in front of the camera and try to stop Alex from talking. He made his mind up early in the discussion and became impatient when the others would not agree. At other times, he showed a keen interest in the discussion and made valuable contributions to the debate. His ideas stimulated discussion even though there were considered to be rather impractical by the other children (See Belbin's 'Plant'). Adults playing more than one role were also observed by Belbin. Belbin acknowledged that the ability to switch flexibly between roles is a skill that characterises effective team members. Simon's behaviour indicated that he was highly strung and prone to irritation (See Belbin's 'Shaper'), and he was liable to lose interest once the initial fascination passed (See Belbin's 'Resource Investigator'). For example, Simon made a choice early on in the Cups and got irritated by the continuation of the discussion, as the following example shows:

Cups

> **Simon**: We have all accepted that this is the best (thick plastic cup) so why are we arguing? (Sounding exasperated) What are we trying to prove?

8.5.3 Cicely

Cicely showed practical common sense and liked to check exactly what had to be done at the beginning of an activity (See Belbin's 'Company Worker'). She also played an important role in keeping the group focused on the evidence they had been given, and referred back to the E1 evidence once the discussion was underway (See Belbin's 'Completer Finisher'). She summarised the evidence the group had considered without making a decision herself, so she kept the group on task (See Belbin's 'Company Worker').

8.5.4 Alex

Alex's behaviour did not reflect any of Belbin's team roles to any great extent, although he showed some attributes of the Team Worker, as he was rather mild and sensitive. He made contributions to the discussions but he was often ignored or interrupted by the other children.

The roles these four children adopted, as discussed above, indicated that although there were some clear similarities between the roles children and adults adopt when working with others, the children's roles needed to include other roles that had not been observed by Belbin in adult teams. The roles identified by Belbin are all roles observed in *high performing* teams, but in this research the children took on roles that did not appear to contribute to the success of a group. Therefore, a new set of role definitions was required to include all the roles children adopt in group work, both roles that do contribute to the success of the group and those roles that do not.

8.6 Team roles in classroom activities

To extend the role definitions, a review of two existing taxonomies (Richmond and Striley 1996; Hogan 1999) relating to the roles students adopt in classroom discussion was undertaken. Both these taxonomies were developed from projects that had involved students who displayed characteristics that had both positive and negative effects on the success of the group and, therefore, defined roles for both high performing groups and low performing groups. The construction of the final taxonomy used in this research drew on both these projects. How these studies informed the development of a new taxonomy is explained in the following sections.

8.6.1 Richmond and Striley's project

Richmond and Striley (1996), working with 15 to 16 year old students in science lessons, studied how the roles the students adopt affect the way the students engage with the task, and the development and articulation of the arguments themselves. They conclude that specific roles and leadership styles developed within groups greatly influence the ease with which students develop scientific understanding. Their study involved an analysis of students' talk when they were working in small groups during four different laboratory-based investigations. Richmond and Striley report that the students' engagement with the discussions was not distributed equally across the groups, and the differences were connected to the social roles the students adopted. They identified four roles as leader, helper and non-contributor (both active and passive). A summary of the characteristics of these roles is given in Table 8.3 below.

Table 8.3 Characteristics of Richmond and Striley's four roles

Role	Characteristics
Leader	Usually able students who generate the group's action plans; co-ordinate the assignments; liaise between students and teacher.
Helper	Competent individuals, acting cooperatively with leader to form action plans and to carry them out.
Non-Contributor: active	Students concerned with 'getting by', engaging in more off-task behaviour than the leader or helper; at times challenging or ridiculing the contributions of other group members.
Non-Contributor: passive	Students who rarely participate in activities and often copy the work from others.

Richmond and Striley provide further classification of the leader role; leaders were characterised by different styles termed *inclusive, persuasive* and *alienating*. The *inclusive* leaders bring up ideas and then involve the others in discussing this idea. The *persuasive* leaders present their ideas and if challenged, often attempt to convert the others. *Alienating* leaders are those who possess strongly held beliefs, declare their point of view and disregard the input of others.

However, examination of the data for this research showed that, although there were children whose behaviour could be categorised using Richmond and Striley's roles, there were children whose behaviour did not fit into any of these categories. For example, there were children, such as Luke in the St Anne's group 1, who directed the action of the group (He suggested that they should sort the cards into 'true' and 'false' in the Bats), but his actions were neither inclusive nor persuasive. His actions did not prevent other children from joining in, but neither did he consult them about his suggestions. Some children, such as Elijah in the Woodstreet Junior group 2, made little or no contribution because they made their minds up early on in the activity, and just did not engage with the discussion with the rest of the group. However, it was clear that some children exerted a more positive effect on the groups' discussions than others, as they acted cooperatively with one another and listened to and responded to one another's contributions.

Although Richmond and Striley identify both positive and negative roles, their categories are rather limited, as they do not identify the nature of the contributions made by the student. For example, it is important to understand how the 'helper' improves the quality of the discussion; acting 'cooperatively' does not indicate what contribution was made to the decision-making process.

8.6.2 Hogan's project

Hogan (1999) examined students' roles during a long-term collaborative task in a sequence of science lessons working with 13 to 14 year old students. She documents the social and cognitive processes that emerged as the students 'pursued a task that required them to transform their observations into knowledge claims through argumentation and persuasion' (Hogan, 1999: 856). Rather than focusing on identifying the children's behaviour in the discussion, Hogan seeks to define the *effect* of the child's behaviour on the reasoning process taking place. Hogan discerns eight social cognitive roles: four that promoted the groups' reasoning process and four that did not. A summary of the characteristics of these roles is shown in Table 8.4.

Table 8.4 Characteristics of Hogan's roles

Roles	Characteristics
Roles that promoted the group's reasoning process	
Promoters of reflection	Students who encourage the group to reflect on and improve the quality of their ideas; this could be expressing a need to improve the ideas or by challenging others' ideas.
Contributors of content knowledge	Students who provide a key resource for the group with their strong conceptual knowledge about the topic being discussed.
Creative model builder	Students who offer imaginative ideas as a model to explain a scientific concept.
Mediators of group interactions and ideas	Students who mediate between conflicts within the groups.
Roles that inhibited the group's reasoning process	
Promoters of acrimony	Students who are openly hostile to fellow group members.
Promoters of distraction	Those who make light of the task and behave in a silly manner.
Promoters of simple task completion or unreflective acceptance of ideas	Those who are so concerned with finishing the task they would write down ideas that had not been agreed by the group; those students who are perceived to be clever, put forward ideas that the others feel they could not challenge (This was not a conscious way of promoting lack of reflection.)
Reticent participants in collaborative knowledge building	Students who make little contribution and/or express lack of confidence in their abilities and ideas.

This distinction between the positive and negative effects of the students on the reasoning process is reflected, in part, in the data for this research. However, it is more a case of 'not promoting the reasoning process', rather than the children's contributions 'inhibiting the reasoning process'. This difference will be discussed further below.

Although the work of Belbin (1981), Margerison and McCann (1990), Richmond and Striley (1996) and Hogan (1999) all illuminated key issues when defining roles for the purpose of analysing teams, none of the existing frameworks were suitable for use with groups of children aged ten to eleven years old. Therefore, a new framework had to de developed for this study to provide a more complete reflection of the behaviour of the children in the activities researched. Thus, a different set of categories was devised to produce taxonomy of roles for children. How this taxonomy evolved will now be explained.

8.7 The role taxonomy for children

As has been explained, although the method used to define the role categories for this research was influenced by the work of Belbin, Richmond and Striley and Hogan, a new set of categories had to be developed. Belbin's work provided the initial impetus for the study of the roles children adopt in group work. The role definitions devised drew on ideas from other research carried out in schools, as both the children's engagement in the discussion (Richmond and Striley's study) and the effects of their actions on the group reasoning (Hogan's study), were identified. Initially, the 20 transcripts were examined and a list of the children's actions was compiled; actions, such as how they contributed to the discussion and responded to one another's points of view were, used as indicators. The actions are given in Table 8.5 overleaf.

Table 8.5 Actions taken by the children in all four activities

	Actions
1	Starts the discussion.
2	Reads out E1 evidence.
3	Directs discussion.
4	Makes a claim.
5	Makes a claim with justification.
6	Responds to others and poses questions.
7	Responds to others and completes another member's sentence.
8	Responds to others to confirm points made.
9	Responds to others with challenge.
10	Responds to others by answering a question.
11	Makes a summary of criteria to be used.
12	Makes a summary of the evidence discussed.
13	Introduces new idea.
14	Reflects on an idea.
15	Changes their mind.
16	Talks off the subject.
17	Makes no contribution.
18	Asks questions of the 'teacher'.
19	Repeats ideas others have made.
20	Investigates (For example, by rolling the cups on the table.).
21	Suggests investigation.
22	Asks other members questions.
23	Brings discussion to a close.

By repeated readings of the transcripts, these 23 actions were then put into 'clusters' of similar actions. For example, those actions that directed the flow of the discussion included 'starts the discussion' (Action 1), 'directing the discussion' (Action 3) and 'bringing the discussion to a close' (Action 23). Another cluster included the actions that were in response to comments made by the other children. For example, 'confirming a point made' (Action 8) and 'answers a question' (Action 10). One cluster included actions that made little or no contribution to the discussions and included 'talking off the subject' (Action 16) and 'makes no contribution' (Action 17).

These clusters helped to build up a picture of the roles children played in terms of the group's reasoning (introducing new ideas, changing mind, challenging responses) and the engagement in the discussion (starting, directing and concluding the discussion). The roles were then allocated a name that gave some indication of the features of the behaviours of each role. Table 8.6, overleaf, gives the details of each role and its characteristics. Extracts from the transcripts are given to illustrate each role are included in the following section.

Table 8.6 Characteristics of the roles developed for this analysis

	Role	Code	Features
Positive Roles	**Chair**	Ch	Asks questions of others for contributions. Suggests what the group can do.
	Discussion Manager	D M	Starts and /or ends discussions. Makes final decision with or without consultation. Directs the group; suggest what action to take.
	Information Manager	IM	Checks on the tasks to be done or validity of evidence. Refers back to the E1 evidence. Summarises evidence.
	Promoter of Ideas	PI	Suggests ideas that may or may not be acceptable to others. Impatient when discussing ideas other than their own. Wants to get the decision made.
	Influential Contributor	IC	Makes claims with reference to data. Responds to others by posing questions or challenging ideas. Suggests a possible decision.
Negative Roles	**Non-influential Contributor**	NIC	Responds to others' comments with agreement or confirming points made. Makes suggestions that are ignored by the others. Agrees with the decision that someone else makes.
	Non- responsive Contributor	NRC	Has own ideas but puts them forward only when asked. May make a different decision to the others. Does not attempt to persuade others to change their minds.
	Reticent Participant	RP	Makes little contribution. May read out E1 evidence but not make any comments. Makes few claims.
	Distracter	Di	Talks about issues not related to the task. Tells long stories that are marginally related to the discussion. Displays silly behaviour.

8.8 Profiles of each role

To explain the definitions, examples are taken from different groups of children in order to exemplify each role. The following table gives an overview of all the groups and the roles adopted by the children. The codes for the roles are given in Table 8.6.

Table 8.7 The roles children adopt in the group

Group	Child	Roles adopted	Number of different roles within the group
St Anne's Group 1			4
	Luke	D M I C	
	Naveed	RP	
	Osei	NIC (becomes I C)	
	Sheerah	I C	
St Anne's Group 2			1
	Alicia	I C	
	Daniel	I C	
	Heidi	I C	
	Junior	I C	
Castle Hill Group			6
	Alex	I C NIC	
	Cicely	IM I C	
	Joanne	Ch I C	
	Simon	PI Di IC	
Woodstreet Junior Group 1			2 (3)
	Amy	NIC	
	Che	IC (some elements of DM)	
	Jillese	NIC	
	Patrick	NIC	
Woodstreet Junior Group 2			5 (6)
	Chantal	NIC Di	
	Elijah	NRC RP	
	Jason	IC (elements of DM and Di)	
	Sharon	NIC Di	

Chair

This role, as has been suggested above, is very important to the success of the group. The chair links the group together and encourages the members to work in a cooperative way. The links are made between each member of the group (Let's listen to each other), the group and the task (We haven't looked at this evidence yet), and the ideas and the reasoning behind the idea (So, why did he say that?). The only example of a child taking up the role of Chair was Joanne from the Castle Hill School group. As has been explained, Joanne directed the group to involve everyone, and she was keen to allow each child to contribute to the discussion. She played a very similar role in all four activities, as the following extracts illustrate:

Gerbils

129. **Cicely**: Well, let's make a decision.
130. **Simon**: Who votes for this?
131. **Joanne**: Do you think we should go round separately? What do you think? Tell me why you don't want that one.

Cups

10. **Joanne**: Okay Alex, you say what you think and then we'll go round.

Bats

68. **Joanne**: You guys, shall we pick up one (a *BAT FACT?* Card) and all discuss it?

Marbles

40. **Joanne**: Okay you guys, just listen. If we read one (Information sheets) and then pass them round.

The influence of a Chair relative to the other roles is discussed in the following sections.

Discussion Manager

The key difference between the Chair and the Discussion Manager, is that the Chair makes a positive effort to include the other children in the decision-making process, but the Discussion Manager does not. The Chair will put forward a point of view, but not before listening to the others' views. The Discussion Manager is more concerned with getting the decision made, and the activity completed, than getting everyone to express their views.

In St Anne's group 1, it was Luke who took on the role of Discussion Manager. In the Bats, Luke directed the children to put aside the false *BAT FACT?* cards, and no one questioned this idea. In the discussion, he did not exclude the others but made no attempt to draw them in, for example, he did not ask the others if they agreed with his decision to put aside the cards. Unfortunately, this meant some important evidence was missed. He brought the discussion to a close in all four activities by saying, for example, 'Are we all agreed then?' or 'Have we decided yet?' In posing these questions, Luke did involve the other children in finalising the decision-making process, but not in forming the decision. The children took it in turns to speak, but no one asked others to make a contribution. This type of behaviour enables a member of the group to avoid taking part in the discussions, which is less likely when a Chair is in a group.

The Discussion Manager is happy to take on a role of directing the procedures of the discussion, but not the substance of the discussion itself. For example, Che (Woodstreet Junior group 1) also displayed some of the behaviour of a Discussion Manager, as she asked the others to read out the *BAT FACT?* cards out aloud. She directed the group in starting off the task, but again, like Luke, she did not ask others to express opinions or explain their ideas. Therefore, should there be anyone in the group who is a little shy, or finds it hard to take part in the discussion, they would not be encouraged to engage in the discussion itself. However, they might be encouraged by the Discussion Manager to take some role in, for example, reading out the cards.

Information Manager

The Information Manager is concerned with using the evidence given to a group. For example, Cicely, from the Castle Hill group, took a key role in bringing the information given to them (E1 evidence) to the attention of the others. When other children in the group moved swiftly to make decisions, Cicely examined the information in great detail before venturing an opinion. She continued to refer to this information throughout the discussions. The following extract is taken from the beginning of the Gerbils, where the other children had already started discussing the merits of each home. The type in italics indicates when comments are taken from the sheets (E1 evidence) about the Gerbil homes to show how Cicely's actions ensured that more of the E1 evidence was considered.

Extract 1

32. **Cicely**: It has a *layer of garden peat, sand* ...
33. **Alex**: *It's made from an old aquarium.*
34. **Joanne**: An aquarium! A fish tank, no! It would like, smell maybe or something ...
35. **Cicely**: It has *a layer of garden peat, sand and gravel.*
36. **Simon**: It would actually like that.
37. **Joanne**: It would smell.
38. **Alex**: Actually, it would be okay.
39. **Simon**: That's their natural environment.
40. **Joanne**: I know.
41. **Cicely**: *There is room for twigs and hay.* Okay...
42. **Joanne**: If it was a new aquarium, it would be okay.
43. **Cicely**: What about this one?
44. **Simon**: This one is like ...
45. **Cicely**: *It's made for hamsters.*
46. **Joanne**: That's okay for gerbils, but it's a bit small. If it's the size of a normal fish tank.

Cicely played an important role in keeping the group on task. She summarised the evidence discussed and drew attention to the specific piece of E1 evidence she used as, for example, in the Bats when she said 'I don't think it is a very good idea to move the bats because it says here ...', and she read from the BAT FACT? Card. Again, in the Marbles, she made the group focus on the E1 evidence when she asked Joanne, 'What does it say on this one (Winston & Katy's sheet)?'. In the Gerbils she checked information about the home asking if a wheel could be fitted into Home 3. Cicely's references to the evidence stimulated the other children to consider the evidence in more detail than they might have otherwise have done. Simon suggested that the gerbils would 'like' the layers of peat and sand found in Home 3, but Joanne thought it would smell. As the children disagreed, they had to debate the issues and *provide justification* for their claims. A key feature of the Information Manager is that their contributions result in more evidence being considered by the group.

Promoter of Ideas

A Promoter of Ideas brings creativity to a group and suggests ideas that may or may not receive approval from the rest of the group. Simon, in the Castle Hill Group, suggested ideas that were individualistic and somewhat unorthodox. For example, he suggested that Home 1 had an air filter (It does not – they are just air vents), that glass was impractical to take on a picnic because cups made of glass would break when you went over speed bumps, and he was concerned that if the books in the library were cleaned on a Sunday, what would happen if a council inspector came to the library on a Saturday. His suggestions promoted the others to examine their own ideas more carefully but his influence may not have always be positive because he was inclined to behave in a silly manner. For example, he acted out sweeping the bats away with a broom and he put his hand over Alex's mouth to stop him from explaining his idea in the Bats. Joanne and Cicely both told Simon to sit down or calm down and between them they managed his behaviour. He did show imagination and a strong sense of fun so, as Belbin (1981) has 'allowable weaknesses' for the Plant role (see Table 8.1), perhaps it should be accepted that a Promoter of Ideas, like Simon, might also play a role that can distract the group from the task. Belbin suggests that 'Plants' needs 'keeping in place' as they must not be allowed to pursue unrewarding lines of thought, yet their potential must be recognised.

Exploring too many ideas might have a detrimental affect on the discussion, but having no ideas is even more limiting.

Influential Contributor

To be considered *influential,* a contributor must have an effect on the way the group reflects on the evidence. An Influential Contributor stimulates the discussion by listening to the contributions of the other group members and making a response to them. In this research, many of the children joined in the debate by saying what they thought, but the key behaviour of Influential Contributors is that they respond to what others said in the discussions and made them think further about the claims they had make.

Sheerah, from St Anne's group 1, is an Influential Contributor in all activities. In the following extract, Sheerah and Osei were discussing the merits of two cages for the gerbils. Sheerah said she thought that Home 1 was too small, and Osei responded directly to her comments by suggesting the home could be made bigger. Sheerah's reply indicates she was listening to Osei and was taking his view into account. She influenced Osei by making him reconsider Home 1 as a possible choice. In his interview, Osei said he wouldn't choose Home 1 'because we thought it was very plain', the exact phrase introduced by Sheerah in the discussion.

Extract 2

33. **Sheerah**: Home 1, what I think ... it's small and it only has a wheel for the gerbil to run around on, and it has a food bowl. It's better with (sic) Home 2, which is bigger.
34. **Osei**: But, with this home you can take the lid off and connect it to a very big aquarium. You can put tubes in and that.
36. **Sheerah**: You could do that, but it's a bit plain.

It is not enough for members of a group just to take part in the discussion, there needs to be someone to guide the group to engage critically and constructively with each other's ideas. The children in St Anne's group 2 all took on an Influential Contributor, role as they did make claims supported by evidence, and they did make some challenges to each other's claims. However, what appears to be lacking was someone to organise the discussion and promote the sharing of ideas, i.e. the role of Discussion Manager and Chair. For example, when Heidi, an Influential Contributor, said, ' I know which one I'm choosing' in the Gerbils, no one asked her to tell the group what this decision was, nor did anyone ask her to explain the reasons for her choice. A Chair might discourage Heidi from keeping her ideas a secret and would ask her to share her ideas. In the Marbles, when Heidi was puzzled by the differences in Hari and Rebecca's conclusions, a Chair might encourage her to explain why she was confused. In this way, the group might have pursued a more fruitful discussion and offered more than one explanation to account for the anomalous data.

Non-Influential Contributor

The Non-Influential Contributor makes contributions, but these may be isolated comments that are not discussed by other members of the group. For example, Jillese, in the Woodstreet Junior group 1, did make small contributions to the discussions, so she is not classified as a Reticent Participant (see below). However, Jillese was reluctant to put forward her ideas once she had made her initial contribution. Again with the influence of a Chair, Jillese might have been encouraged to be more assertive and put forward her own ideas, rather than just agreeing with other speakers. Jillese was more active in the Marbles, which was the last activity in the research programme, and this could indicate that she had gained more confidence over the year. Another explanation for Jillese's increased contribution is that she could have identified more closely with the subject matter; at this time Jillese's attendance at school was erratic and as a result her class teacher felt Jillese had not formed strong relationships with her class. In the

Marbles, the group considered that the differences in Hari and Rebecca's conclusions were because the children did not get on well together. Jillese said she felt that Hari and Rebecca should have tried to work together even if they did not get on together. These comments may reflect her own feelings of how groups need to work together.

Daniel, from St Anne's group 2, is also identified as a Non-Influential Contributor, as he put forward ideas that were not taken up by the group, as the following extract from the Cups illustrates:

Extract 3

20. **Daniel**: Because, I'll tell you why. Because we don't want to ... you know...
21. **Junior**: (interrupts) This one can get knocked over easily (thin plastic cup).
22. **Alicia**: You're right.
23. **Daniel**: If you're outside, you don't want it to be too heavy.
24. **Alicia**: That glass one could break; if you go a on picnic it can smash. That's why I chose that one (thick plastic cup).

Daniel joined in the discussion, but he was interrupted by Junior and did not complete his sentence. The group overlooked his comments about a heavy cup and Alicia continued justifying her own choice of cup to take on the picnic. This did not appear to cause Daniel any resentment as he contributed later on in the discussion, but to reinforce the others' ideas rather than put forward his own. The Non-Influential Contributors have the potential to make a positive contribution to the performance of a group, but they need someone to draw them into the discussion and recognise the importance of their input.

Non-Responsive Contributor

The Non-Responsive Contributor makes contributions to the discussions, but is not influenced by the comments of others in the group. For example, in the Cups Elijah, from Woodstreet Junior group 2, held a different view to the others as he chose the thin plastic cup rather than the thick plastic cup. He stated he thought the thin plastic cup was best and did not change his mind, despite the fact that the group discussed ten different points *against* taking the thin plastic cup. Elijah was not influenced by these arguments, nor did he make any attempt to convince the others of his choice. He did make contributions, but was not prepared to engage in discussion about the other children's choice. When challenged, he offered no justification for his claim and dismissed the opposing arguments without justification, as the following extract illustrates:

Extract 4

20. **Elijah**: Yes, I think this one because you can throw it away afterwards ... it's disposable.
21. **Jason**: But then, if you throw it away, you will have less cups.
23. **Elijah**: You just buy some more!
24. **Jason**: What if you ain't got the money?
25. **Elijah**: I don't know.

This extract shows that Elijah did have ideas of his own, yet he appeared to be reluctant to take part in any debate. Perhaps if Elijah had been in a group with a Chair asking him to explain his views as, for example, Joanne did in her group when she said, 'What do you think? Tell me why you don't want that one', he might have taken a more influential part in the group decision-making process. In having to explain his answer to the other members of the group, Elijah could have convinced the others of the merits of his idea as he provided justification for his choice. Alternatively, when articulating his reasons, Elijah may have perceived a flaw in his argument and changed his mind. As it is, it is impossible to say whether Elijah could be persuaded to take a greater part in the discussion, as the rest of his group appeared content for him to make a different choice.

Reticent Participant

Reticent Participants make few contributions to discussions. There are two children, in this research, who adopted such a role: Naveed in St Anne's group 1 and Elijah in Woodstreet Junior group 2. Although both are classified as Reticent Participants, the reasons behind their reluctance to participate appear to be different. Naveed is a pupil who spoke English as an additional language. Her contributions to the discussion were minimal, limited possibly by a lack of confidence in speaking. She did read out E1 evidence, so she showed a willingness to take part in the activity in some capacity. Perhaps Naveed's contributions could have been enhanced had there been someone in her group to encourage her to say something, such as 'Let's listen to …' as Joanne does in the Castle Hill Group.

Elijah played two roles, one of a Non-Influential Contributor as has been discussed above, but at times he took on the role of a Reticent Participant. The transcripts show that there were many times in the discussion where Elijah said nothing at all. In some activities, Sharon did ask Elijah what he thought, but his answers were short and abrupt, and Elijah did not engage with the discussion. In some activities, the video recording shows that he gazed around the room in the middle of the discussions and gave the impression of being bored. Whether Elijah found the topics under discussion boring or whether he preferred to work on his own, and not in groups, is impossible to tell. Further research is required to see whether children who adopt these roles can be encouraged to be more participative in group work.

Distracter

Children who take on the Distracter role take the group off-task. Two types of behaviour have been observed that distracted the group in this way. One was Simon's silly behaviour, as described earlier, but Simon's behaviour was coupled with a strong sense of humour. As has been explained, Simon acted out sweeping the bats off the ceiling. Having realised that in killing a bat he would be fined £2000, he made three sweeps in the air and said '£6000. I've just wrecked the budget!' Some people might find such humour inappropriate and distracting, but for others humour can promote team spirit.

The other type of distracting behaviour entailed children telling long stories that had a tenuous link with the discussion. Chantal and Sharon both spent time telling stories about events in their lives, some of which were relevant to the discussion, and some which were not. This was particularly evident in the Cups where Chantal told ten separate stories about the dangers of glass cups that break and thin plastic cups that split. Experiences in her own life provided her with strong evidence to support her claim that glass should not be taken on a picnic. In the Bats, Chantal and Sharon discussed a film about witches with bats coming out of their mouths which then led onto Sharon describing her experiences in a glass-bottomed boat in Jamaica and these stories did not contribute to the debate about what to do about bats living in the roof of a library. Chantal recognised they had been sidetracked and returned the topic under debate by saying 'Anyway, back to the bats'. Perhaps the discussion would not have drifted away from point, if the group had included a child taking on the role of Chair and steering the conversation back to the central issue. This type of distraction wastes time and if other members of the group are not interested in the stories, they may become bored and lose interest in the discussion all together.

8.9 How the roles impact on the argumentation process

The above sections describe the roles adopted by children in this research and gives examples of their behaviour. Taken together, they show how the behaviour of individuals influences the effectiveness of the process in the group and in turn, whether the potential relevance of all available evidence has been realised. It is now important to consider the issues of group effectiveness more directly. As the assessment of the group's success or failure has been judged on specific criteria, how the roles impact on each of these criteria is now considered.

a) How is evidence used by the children?

Although it is not essential for a group to use *all* the E1 evidence, a group cannot consider whether evidence supports a particular view, if the evidence is ignored in the first place. It is proposed, therefore, that a group that explores a wide range of the evidence demonstrates quality decision-making skills. The data suggests that one particular role has a key influence on how much evidence is evaluated by the groups: the Information Manager. The Information Manager has a key role to play in ensuring that the group uses a wide range of the E1 evidence, as Cicely, in the Castle Hill Group, demonstrated. The Castle Hill Group discussed more of the E1 evidence than any of the other groups. In contrast, the Woodstreet Junior Group 2 used the least amount of E1 evidence. The data indicate that this group spent as much time, if not more than the other groups, on the activities. However, when considering their decisions they limited the amount of evidence they discussed because they spent much of this time discussing irrelevant issues. This was due to the Distracter role played mainly by Chantal and Sharon.

The role of Distracter is considered to have a negative effect on the way the group carries out decision-making activities, as it does not contribute positively to the group process, consumes potentially valuable time and may contribute to a lack of concentration in other members of the group.

The role of Distracter can be managed and may not always result in evidence being ignored. For example, when Simon adopted the role of Distracter and the discussion became irrelevant, Joanne and Cicely were quick to bring the conversation back to the point. Perhaps the negative effect of the Distracters was more prominent in Woodstreet Junior because of the roles the other group members adopted. The children in Woodstreet Junior Group 2 adopted four negative roles; no-one took on a role that ensured the discussion kept to the point.

As discussed previously, having a Discussion Manager like Luke (see section 8.6.1), may result in less evidence being used. Unfortunately, without any one to challenge Luke's decision, a Chair for example, his actions resulted in some important evidence being missed. However, this is not to say that the role of Discussion Manager will always have this effect, but it does emphasise the need for children to engage with the decision-making process *as a group*.

b) How many claims are supported by data?

It is considered that in the four research activities, the evidence to support different claims is available and, as the 'answer' to each activity is not obvious, the children have the opportunity to explore different choices. Therefore, they should be able to select evidence to support a range of claims. So, if children fail to justify their claims, it is not for want of some appropriate evidence.

Examination of the transcripts has illuminated certain roles that encourage the children to justify their claims with the result that the full potential relevance of evidence is made clear. The Influential Contributors make claims supported by evidence and, if group members adopt this role, it is possible that they will engage in the process of argumentation. However, the data suggest that just having the claims made explicit is not enough; children can make a series of claims supported by evidence that oppose each other's claims yet they do not engage in any argumentation. This is because they do not challenge each other's claims or the evidence to which they appeal. Therefore, they do not explore the validity of the claims in a critical way as no one is expected to defend their position. It is important then to identify the role that promotes the reflection on the validity of the supporting evidence.

c) How many alternatives are explored?

In each activity, there are a range of possible options and explanations for the children to explore. The greater the number of possibilities considered, and the more evidence explored, the greater the chance of a solution being reached that can be fully justified. The final choice should be justified with evidence that supports a choice and also with evidence that refutes other possibilities.

The exploration of alternative choices involves a suspension of judgement and the consideration of opposing views. Children who make their decision first, and then look for evidence to support their choice, restrict the number of alternatives explored. A Chair would ensure that the group explores all views held by the group and the Information Manager would draw attention to the given evidence. Together, these roles have an important influence on the decision-making process.

d) Is sustained dialogue maintained?

The role of Chair is very important to the success of the group. The Chair links the group together and enables the members to work in a cooperative way. The links are made between each member of the group, the group and the task, and the ideas and the reasoning behind the idea. It is possible that this role is the most crucial for the success of a group.

The Discussion Manager is happy to take on a role of directing the procedures of the discussion, but not the substance of the discussion itself. Therefore, should there be anyone in the group finds it hard to take part in the discussion they may take some role in, for example, reading out the cards because there is a Discussion Manager in the group, but they would not be encouraged to engage in the discussion itself.

8.10 The role composition of the groups

As shown in Table 8.7, it is clear that the composition of the groups was very different in term of the roles represented within each group. The total number of roles indicates the range of roles found within a group. When a child played another role just, for example, in one part of an activity, this is indicated in brackets. In some groups the children adopted a range of roles, for example the Castle Hill Group, whilst others adopted very similar roles to each other, for example St Anne's Group 1.

It is important to compare how such groups differed in the way they argued and used evidence as, already noted, Belbin (1981) found that the most successful management teams were those with a good spread of team roles. The data for this research shows that the group with the greatest spread of roles, the Castle Hill Group (six roles), was the most successful team, but this cannot be the whole story as the children in Woodstreet Junior Group 2 also adopted a range of roles (five) yet, as discussed in chapter 7, the use of evidence and engagement with the discussion were very different for these two groups. Thus, it is important to examine not only the range of roles, but also whether these roles have a positive or negative effect on the way the group works together. How the composition of the group affected the ways the children used the evidence to come to decisions is now examined.

8.10.1 Groups where the children play a range of roles

In the Castle Hill Group the children played six different roles; there were four Influential Contributors, one Non-Influential Contributor, one Information Manager, one Chair, one Distracter and one Promoter of Ideas.

The Castle Hill Group was the most successful whichever criteria were considered. They were prepared to challenge one another's ideas and to change their minds. They worked together and consulted each other; they respected other's views even though they disagreed and sought to establish the merits of alternative viewpoints. The final decision made did not depend on any one child and they reached a consensus in all four activities.

They explored all possible choices for the gerbil homes and the cups for the picnic and both the positive and negative aspects of all of these choices on *every* occasion (they are the only group to do this). In the Bats , they considered five different options for how to deal with the bats that are damaging the library (the highest number of all the groups), and again considered both the positive and negative implications of these options. In the Marbles, they considered five different explanations for the anomaly presented by Rebecca and Hari's different conclusions from the same set of results. Again, this is the highest number of explanations offered by all the groups.

The Castle Hill Group also demonstrated sustained argumentation in all of the activities. As explained in chapter 7, the discussion maps indicate that this group had a much more varied and complex pattern in their discussions than the other groups. In the Gerbils, the children started with short discussions that led to an argument being put forward. This episode then led to a review of evidence that engendered further discussion and further review. Any new arguments were discussed and there were many examples of when this discussion led to a new argument being put forward. This group always had episodes where one of the children, usually Joanne or Cecily, clarified details of the E1 evidence. For example, in the Gerbils Joanne read that Home 1 is big enough for one hamster. She enquired whether the home they were choosing for the gerbils is for one or more gerbils. She was the only child to pick up on this piece of evidence and it was crucial to the choice as gerbils are social animals and should not be housed alone; the task they were set was to choose a home for more than one gerbil. This behaviour demonstrates a more enquiring attitude than shown by other groups who rarely queried any of the evidence. However, children in the other groups were not afraid to ask the meanings of words that they did not understand and, thereby indicated that they were at ease with asking questions of the researcher. It is likely therefore, that their failure to ask questions about the evidence was not because they felt intimated and felt unable to clarify matters that concerned them.

The discussion maps show that in other activities, the Castle Hill Group's discussion included many examples where the discussion of one argument led to a refined or alternative argument being put forward. In the Marbles, the children put forward tentative arguments characterised by phrases, such as, 'If it was ...' or 'It might ...' and these arguments also led to discussions where they eventually agreed on a claim or a new argument was formed.

Another sign indicating that this group works well as a team is that they did co-construct some of the arguments. Sometimes this may mean a child read or discussed evidence that led another child to make a claim and, at other times, a child made a claim for which another provided the justification, or further justification for the argument. To co-construct an argument requires the children to listen to what each other is saying and to respond to what has been said. However, it is possible for children to listen and respond to each other and still make individual arguments. It is worth noting that the Castle Hill group put forward eight co-constructed arguments, as did St Anne's group 1, but the Woodstreet Junior group 2, identified in this research as having the weakest skills in using evidence, make no co-constructed arguments in any of the activities.

The way the children in the Castle Hill Group spoke to each other indicates that they have been taught how to listen to each other and take it in turns to speak. Their talk was littered with phrases such as 'Please may I say something?', 'May I say my reasons now?', and they put up their hands if they wanted to respond to the child speaking. They were also searching for agreement as can be seen when Joanne raised the issue that Home 3 is an old aquarium, a factor she found unacceptable, yet she asked the others 'Now, who agrees that that's acceptable?'. The three other children raised their hands in response. 'I suppose you're right', Joanne replied. Until the four children in this group agreed on a decision, the discussion continued. This was the same in all four activities.

Overall, the Castle Hill Group showed the highest quality skills in the use of evidence; they used evidence to support and justify the claims they made and they explored together the evidence that both supported and challenged these claims.

8.10.2 Groups where the children play similar roles

In St Anne's Group 2 the children each played just one main role; there are four Influential Contributors. This group rank fourth for the number of justified claims made; many (44%) of these are made by one child, Heidi. However, the number of justified claims made (32) was very similar to the Woodstreet Junior group 1 (31). The E1 evidence they explored in the activities was the same amount as both the groups from Woodstreet Junior School, with most being used in the Bats , so this is not a distinguishing feature in this case.

They explored all possible options for the gerbil homes and the cups for the picnic and did explore both positive and negative aspects of most of these choices. However, they only considered one possible decision in the Bats and offered just one explanation in the Marbles.

In the first activity, the children started with a series of arguments and then moved towards a pattern where the arguments were followed by some discussion. This pattern was found again in the Cups and Bats but in the last activity (the Marbles) the children discussed issues and then proposed an argument. Again, there was very little review in any of the activities. They did co-construct five arguments, four of which were in the Marbles .

8.10.3 Groups where the children play negative roles

In the Woodstreet Junior Group 2, the children played five main roles; there was one Influential Contributor, two Non-Influential Contributors, one Non-responsive contributor, one Reticent Participant and two Distracters. Jason, however, did show elements of the Discussion Manager and Distracter roles, but these were not shown consistently in all four activities.

This group put the second highest number of justified claims. However, 41 of these justified claims were put forward in the Cups , where 29 of justified claims were about the same subject, that glass was likely to smash and the subsequent safety aspects of taking a glass cup on a children's picnic. As discussed previously, the E1 evidence explored by this group was the same amount as the other group from Woodstreet Junior School and St Anne's Group 2. This group did, however, demonstrate the weakest skills when considering both positive and negative issues about the possible choices in the activities. Although they discussed the possibilities of all the homes in the Gerbils, they did not look at both positive and negative issues of the possible choices. They explored only the disadvantages of both Home 1 and Home 3 and only the advantages of Home 2. It is this lack of exploration of both sides of the evidence that suggests this group had poor argumentation skills. However, in the conversation on choosing the cup to take on the picnic, they did raise both positive and negative issues about each cup. In the Bats , they discussed only one option in choosing what to do about the bats (as do St Anne's group 2), but in the Marbles they did not put forward any explanation at all, in contrast, all the other groups make some attempt to explain the anomaly, and the Castle Hill Group suggested five possible explanations. Again, this is another indicator of poor skills in argumentation, as, although they did see the anomaly, they seemed to be unable to reflect on what the evidence might be telling them.

The discussion maps show that this group's discussions were characterised by a series of arguments being put forward that did not relate to each other and there was little or no discussion about each argument put forward. Sometimes the arguments that followed each other were very similar to previous ones and served to support or consolidate a point being made, but at other times the arguments appeared to be unrelated. This demonstrates that the children were not ignoring each other, but they did not challenge each other's ideas or see how the evidence could support a different point of view. There was no sense of the group discussion moving forward to a joint agreement. They struggled to engage with the Bats and spent much of the time reading out the cards and clarifying the meaning of the words (e.g. 'preservation'). Also, they did not use the evidence to review their plans or to reformulate a new plan. For example, Amy's plan that included poisoning the bats clearly needed revision in the light of the evidence that you can be fined up to £2000 for killing a bat, yet this point was not discussed within the group, nor did Amy change her mind. In the Marbles, Jason recognised that the conclusion of Rebecca does not match the results written down as the following extract shows:

> 105. **Jason**: In this one (Rebecca's), they got it wrong. It says the marble rolls down the glue tube fastest, but their results show that the bubble wrap is first.

Yet, despite having made the group aware of this crucial point, they did not recognise the importance of this piece of evidence and the children did not discuss how Rebecca could have reached such a conclusion. Despite the fact that the group clearly established that Rebecca's has the same results as Hari, although her conclusion is different, Jason did not engage the others in exploring *why* Rebecca has made a conclusion incompatible with her results. No-one in the group offered any ideas to explain what might have happened (i.e. the Promoter of Ideas role), and Jason did not pursue the matter any further. The rest of the group was more concerned with choosing which surface they thought the marble should roll down faster. Without someone suggesting that they needed to consider why there was such an anomaly, the group continued on a different agenda.

Conclusion

It has been proposed that one of the key reasons why groups of children follow different procedures during decision-making activities is related to the roles they adopt in the discussions. The findings of this research suggest that the most successful group comprises children adopting a range of positive roles and that one of these roles must be a Chair.

Teachers already make judgments about which pupils should work together and, in many schools, the most common criteria for deciding the composition of groups are ability and behaviour or social relationships (Pollard et al. 2000). If the successful working of groups of children can be attributed to the roles children play, then this has implications for the ways teachers organise the groups in their classes. If a teacher can arrange the groups in the classroom so that the groups incorporate as many positive roles as possible, then this may lead to more effective use of evidence when the children have a group decision to make. Also, it may be possible to teach children about the effects of the roles they adopt on the success of a group and about the skills of collaborative work as Jarvis (1993) suggests.

Belbin (1981) indicated that successful business teams that recognised they had an imbalance of roles could compensate for this weakness by appointing someone to cover this missing role; the more conscious a team was of its strengths and weaknesses, the easier it was to adjust. Perhaps children could be taught how to recognise the roles they play and to take on roles they would not normally adopt? If so, teachers could develop more effective group work in their classes for *all* children, not just those who naturally adopt positive roles when working in a group. At this stage, this research can only speculate on this outcome and further research needs to be carried out to test this hypothesis. These points will be discussed further in the next chapter.

The findings reveal that the role of Chair could be significant to a group's success. If, for example, a group includes a child adopting the role of Chair, a wider range of arguments may be considered and the group may be encouraged to reflect on the validity of the evidence used to justify these different arguments. Selecting the composition of the groups by role may lead to an overall improvement in the children's levels of argumentation.

Summary

Some of the reasons why some of the groups of children are more successful in working more collaboratively have been explored and it has been suggested that, like management teams, the roles the children adopt affect the success of the whole group. The meaning of 'success' for groups of children working together has been defined in terms of the way evidence is explored and used in justifying arguments, and also the overall process of argumentation the group follows. It appears that there are key roles that promote good practice in the way evidence is used. The findings show that some children can appreciate that evidence needs to be explored, weighed up and may result in different conclusions. Therefore, we need to know how best to promote these skills in all our pupils. This may be in the way the groups are selected and also how the children come to an understanding of the value of evidence through the way they are taught science in the classroom. The next chapter explores the implications of the findings of this research in more depth and suggestions are made for improvements in the way children are taught to consider and evaluate evidence.

Chapter 9 Conclusion

9.0 Introduction

The focus of this chapter is to identify the contributions this study has made to the field of research into the way children reason and use evidence in decision-making activities in science. It has been argued that science education has the opportunity to develop children's scientific reasoning skills by presenting them with activities where they have to use evidence and argue to come to decisions. This research is about how capable children, aged ten to eleven years old, are in using these skills. The findings have important implications for teachers and teacher development and have led to recommendations being made for current practice in primary schools.

First, the research questions are revisited in order to reflect on the extent to which these questions have been answered. The main findings of the research are summarised and then recommendations are made for teachers concerning the way they teach science and the way they organise children in their classes for group activities. It is argued that teachers should use particular types of activities in science to develop children's skills in debate and the decision-making process. Implications for teachers concerning pedagogical practice in science teaching are then discussed. It is suggested that teachers will need to plan the nature of the discourse so that children become more accustomed at talking through scientific views themselves (Mortimer and Scott 2003).

An important recommendation, arising from this research, is that children need to be made aware of the preferred roles they take on in group activities and they should be taught about the contributions each role can make to the success of the group. They can then be taught how to take on other roles in order to meet the needs of their group, should it be necessary. It is proposed that an understanding of the contribution of different roles can make, will lead to improved group work, where all members are able to make valuable contributions to the debate and decision-making process.

The research methods, designed specifically for the study, are evaluated and it is concluded that they have enabled the research questions to be answered. Extending the questions, to include a study of the roles children adopt in the group discussions, has been judged as a useful approach to take. Nevertheless, it is recognised that there are some limitations of the research method and so modifications to the method are suggested.

Finally, new directions for further research are identified and proposals for research concerning the teaching of the use of evidence and also about the composition of groups are then put forward.

9.1 Reflection on the research questions

Before the contributions of this research are considered, it is important to reflect on the extent to which the research questions have been answered. The research set out to answer these two key questions:

1. How do children make use of evidence to justify the decisions they take when they work in a *group*?
2. How do they make use of evidence to justify the decisions they take when working as *individuals*?

To answer these two questions, a further set of more specific questions was addressed. These questions were:

a. Do they explore all the evidence made available to them?
b. Do they use evidence to support and justify their choice?
c. Are there any differences between the ways they use evidence presented in different formats?
d. Can the way they use evidence be identified as different levels of performance?
e. Do they demonstrate different levels of performance when working as individuals rather than in groups?

These questions were addressed by presenting groups of children with scientific decision-making activities where they could use evidence to come to a decision.

The methods used in this research have provided data that enabled these questions to be answered and were addressed in chapter 5. The analytical techniques, described in chapter 6, used to analyse the data were effective and have provided insights into the ways children make use of evidence in decision-making activities. Levels of performance in children's argumentation skills were identified using discussion maps designed specifically for this study. The data analysis enabled comparisons to be been made between the way children work in a group and the way they work as individuals to answer the two key questions. The significance of the findings and the contributions they make to the understanding of children's scientific reasoning skills are considered in the next section.

9.2 A summary of the main findings of the research

The findings of this research were presented in chapters 7 and 8. In chapter 7 findings about the way evidence was used by the groups of children were discussed. The findings reveal that children, aged ten to eleven years old, demonstrate a range of skills in using and evaluating evidence. In particular the results show that:

- some children review most of the information given to them in the decision-making activities, whilst others appear to ignore much of the information;
- children are capable of making claims supported by evidence, and they can engage in the elaboration of each other's arguments without the intervention of a teacher;
- some children, when given a range of choices, explore all the possible alternatives in their discussions whilst others only explore some of the alternative choices;

- children's argumentation skills vary. Some children discuss each other's ideas and expect evidence to be used to justify claims made. Other children merely put forward their own views and do not expect to be challenged or to oppose another child's claim with counter arguments.

In chapter 8 the findings about the effects of the group were presented and it was shown that:

- the roles adopted by the individual children had a key influence on the way the groups discussed and used evidence;
- the variety of roles adopted by the children within a group influences the ways evidence is used.

These findings provide a further understanding of the ways children, aged ten to eleven years old, make use of evidence in decision-making activities. These contributions are discussed in the following section.

9.3 The contribution of this research to the understanding of children's scientific reasoning skills

The findings of this research have provided insights into ways children's use of evidence in decision-making activities in science can be assessed. First, they have shown that it possible to provide activities for children that promote discussion and therefore make their thinking visible. Second, the research has demonstrated the levels of argumentation that children, aged ten to eleven years old, can be expected to demonstrate.

This thesis puts forward the case that, by expecting children to explain their ideas, by encouraging them to share their ideas, and by allowing them to argue rationally to solve problems together are ways through which scientific reasoning skills can be demonstrated. If opportunities for discussions in classrooms are rare, the amount of talking children is expected to contribute is small (Mercer 1996). However, if teachers can be convinced of the value of group discussions, then maybe group work will again become a feature of the primary school classroom. The next two sections summarise how these conclusions have been reached.

9.3.1 Can children's thinking be 'made visible'?

To understand how children use evidence to come to decisions, it is important to be able to 'see' how they are thinking. As discussed in chapter 5, the findings of this research show that it is possible to make children's thinking visible when they are working autonomously in small groups. Making thinking visible is often associated with scaffolding, where students are prompted to explain their ideas by a teacher (Linn 2000). However, this research shows that children talking, without teacher intervention, can still provide evidence of their thinking because some children provide the scaffolding themselves.

When children are presented with a group task where a choice has to be made, the reasoning shaping their choices can be made clear when they demand reasons for alternative views and ask for evidence to justify counter arguments. The data show that if the children shared their ideas, declared different views and challenge alternative opinions, they exposed their thinking about the evidence they are considering. However, where children did not share their ideas, it was not possible to see how evidence was being used. As explained in chapter 7, some children kept their opinions to themselves and, as noone in the group challenged them to reveal their decision, they did not expose their thoughts on the choice they had made. However, this research has shown that where groups did talk to each other about the merits of the available evidence and did make their choices obvious, it was possible to analyse these discussions in order to make judgements about the quality of their scientific reasoning skills.

9.3.2 Can the quality of children's scientific reasoning skills be assessed?

To assess children's scientific reasoning skills there has to be some measure by which the quality of their skills can be judged. Venville (2002) has studied children's talk to look for aspects 'good thinking' and identifies good thinking as:

> the process in which people are engaged when they are able to solve a difficult or challenging task and which results in an improvement in a person's intellectual power
>
> (Venville 2002: 36)

In the research reported in this thesis, criteria have been established from the data that has been used to identify the quality of children's scientific reasoning through their argumentation skills. In chapter 6 it was explained that parameters, selected to identify good argumentation in children, were derived form Mitchell's (2001) parameters of good argument. The data show that children can give reasons to support their claims, although some need prompting to do so. When children are working autonomously, without teacher intervention, this prompting must come from the children themselves. The findings show that only some children were prepared to challenge one another's views and ask for evidence to support a claim being made. Some children make their decisions independently of the group and yet are persuaded to change their minds by contradictory evidence whilst others remained unconvinced by a stronger argument. The characteristics used in this research to identify a high level of children's argumentation skills are that they:

- give evidence in support of a claim;
- request others to give evidence to support a claim;
- demand explanations of alternative viewpoints;
- are prepared to be convinced by a stronger argument.

In contrast, children whose level of argumentation skills is lower:

- do not challenge opposing views;
- do not demand evidence for claims counter to their own;
- are not prepared to change their mind, even when faced with evidence that supports a counter claim.

The data show that the argumentation skills of children, aged ten to eleven years old, suggest that some children can reason about decisions in scientific activities whilst other children cannot as they are inflexible in their thinking. Examples were given in chapter 7 of children who were convinced by others in the group to alter their decisions. For example, in an activity where the group had to choose a home for a gerbil, three of children want to choose an old aquarium. One of the children, Joanne, was unhappy with this choice and said, 'I know you are trying to persuade me but it is the thing I don't really like ... is thought of it... having fish in it'. Other children in the group argued that the aquarium, because it contained sand and gravel in which the gerbil could tunnel, was most like the gerbils' natural environment. Eventually Joanne was persuaded by their counter claims and she did choose the old aquarium despite her initial reservations.

Children with less sophisticated reasoning skills appear to make up their minds before any discussion takes place and they are not influenced by the arguments of other members of the group. In another activity where children had to select a cup to take on a picnic, one of the boys, Elijah, chose a thin plastic cup. Other children in the group argued that these cups could split and cut someone's lip, that the cups were easily knocked over and the drink would be spilt and that they were easily squashed. Elijah remained unconvinced and was not persuaded by these arguments.

Factors to account for the differences in children's argumentation skills need to be considered so that recommendations can be made in order to develop children's reasoning skills in scientific activities.

9.4 Factors affecting children's scientific reasoning skills

From this study, two key possibilities emerge from the data that might account for the differences in children's scientific reasoning skills. In this research the children who demonstrated the most sophisticated reasoning skills, had the highest predicted grades for their Key Stage 2 SATs, suggesting that that children's scientific reasoning skills might be linked to ability. As discussed in chapter 5, predicted grades were used in this research as an indicator of ability as this was only relevant information held on the children, which was common to all three schools.

The children with the most advanced scientific reasoning skills were taught by a teacher whose specific aims were to develop pupils' thinking skills in science lessons. This finding suggests that children's scientific reasoning skills might also be related to the pedagogical style adopted by the teacher. These two reasons are now considered in the light of the findings and other research in the field.

9.4.1 Is the quality of children's scientific reasoning skills related to their ability?

In this research, the most able children, Castle Hill Group, were those whose predicted science SATs grades were level 6; the expected attainment in science at the end of Key Stage 2 for the majority of pupils is level 4. They demonstrated good scientific reasoning skills in decision-making activities and sophisticated argumentation skills. Ratcliffe (1996), in her research on decision-making in groups of secondary school students, found that the higher achieving groups were able to sustain reasoned argumentation more fully. This trend has also been found in this study as the children in Castle Hill Group, the most able of the five groups, proved to be the most successful group in all the activities for this study. The children in least able group, Woodstreet Junior Group 2, with predicted grades of between level 3 and 4, proved to be the least successful group. These results suggest that the development of scientific reasoning, shown through children's argumentation skills is likely to be linked to their ability. Yet, the data show that children of similar abilities do not always demonstrate similar argumentation skills. For example, in the Castle Hill Group, the individual children showed *different* skills in argumentation to each other, although they had the same predicted grades for their SATs (see Appendix 8). It is proposed that factors affecting the group's success include not just their ability but also the way they worked together as a group.

The second issue is whether the scientific reasoning skills of children might be linked to the pedagogic style of their teacher. This issue will now be discussed in the light of the findings of this research.

9.4.2 Is the quality of children's scientific reasoning skills related to the pedagogical style of the teacher?

Questions have been raised by the findings concerning the effect of the teaching style on the way children use evidence. The findings show that the Castle Hill Group, taught science by a specialist science teacher rather than a generalist primary teacher, showed greater skill development in terms of their use of evidence and the argumentation process. As discussed earlier, their science teacher reported that developing children's thinking skills in science was a key target of his teaching and he explained that the children were expected to contribute to discussions about ideas and not assume the answers would always be given to them by their teacher. Possibly, his teaching style has led to the children in his class having more developed scientific reasoning skills.

As discussed in chapter 4, research shows that teachers who are not confident with their subject knowledge are less likely to teach creative lessons and challenging lessons. Peacock (1997) comments that teachers with less well-developed subject knowledge tend to 'close down' discussions whilst those who are confident in their knowledge sustain open-ended discussions allowing children to share and discuss partially formed ideas. In coming to decisions, discussion about partially formed ideas is crucial to the argumentation process. However, the data from the research reported in this thesis can only suggest that teaching style contributes to the development of these skills; this point is discussed further in section 9.7.4.

The teachers at Woodstreet Junior School were not science specialists and the argumentation skills demonstrated by the children from this school suggest they are not accustomed to working *collaboratively* in small groups. Although, as the children did work *cooperatively* together, it is likely that they were used to working together in small groups. The differences between working collaboratively and cooperatively can be clarified by reference to the work of Bennett and Cass (1989). They identify children working *in* groups, as working together just in a physical juxtaposition where cooperation is limited and off-task talk is high. These behaviours mirror that shown by the Woodstreet Junior School groups. In contrast, Bennett and Cass observed children working *as* groups, who had been taught to work within a particular model of group work where the groups stayed on task and cooperated together.

There is another factor that could account for the success of the Castle Hill Group that is related to their ability. Teachers of less able children feel constrained to simplify the thinking process and give children tasks that are conclusive in order that they do not encounter any misconceptions (Linn 2000). However, Mercer (2000) reports that children taking part in collaborative problem solving activities:

> may have helped them become more able to generate the kind of rational thinking, which depends on the explicit, dispassionate consideration of evidence and competing options.
>
> (Mercer 2000: 159)

A teacher of more able children may not feel constrained by time limits to close down discussions and would allow children more time to think for themselves. Teachers who do not feel confident with allowing children to discuss ideas on their own, need to be convinced that discussion in decision-making activities promotes children's learning. They also need the opportunity to develop their pedagogical skills in order to facilitate such approaches. When a teacher controls discussions, sometimes children's views are ignored (Mortimer and Scott 2003), so teachers will need the skills and confidence to allow children to discuss ideas that may be in conflict with the accepted scientific view. Teachers will need to be convinced that discussion and argumentation are essential components for the learning of science and they will have to be able to develop pedagogical strategies that will both initiate and support argument (Osborne et al. 2001).

Primary school teachers will also have to consider where in the curriculum these types of activities are best located as they are often responsible for the teaching of all curriculum areas as subject specialists teachers are not common in primary schools.

9.5 Where should collaborative work be located in the primary school curriculum?

At the outset of this research it had been hypothesised that the children would reason and use evidence differently when evidence was presented in different ways. It has been proposed that children would be more familiar with evidence presented in charts or tables as these are the styles teachers are expected to use by the science National Curriculum (DfEE 1999b).

However, children's skills of reasoning and argumentation have been shown to be the same whether the evidence was provided in the familiar tables of numbers or whether they were given pieces of information in text or pictures. As reported in chapter 5, the activities in this research engaged children in scientific decision-making activities. The findings show that the amount of evidence reviewed in the discussion, the number of justified claims and the number of alternative choices considered were not affected by the way the evidence was presented in the activities. The data suggest that the roles children adopt in decision-making activities did not appear to have been influenced by the way data was presented and that the roles of the children were consistent for the four different activities.

Ratcliffe and Grace (2003) have also observed consistency in approach to discussion in older children. For example, some children adopt a passive role in discussions about different scenarios, agreeing with the opinions of others in the group. This finding is very important for primary teachers as it suggests that the skills children use in coming to decisions, might well be the same whether the context of the decision was based in a history, in a English or in a science activity. As suggested in chapter 2, children need to be better prepared to take decisions drawing on a variety of sources of evidence, so it is important that lessons in a variety of subject areas include the teaching and development of these skills. However, this research has focused on group work in using scientific evidence and the next section considers the part science activities can have in developing children's reasoning skills through discussion and argumentation.

9.5.1 Teaching argumentation through science

As discussed in chapter 2, many of the controversial issues that will adults of the future to make decisions will be science based and so children need to be prepared to make decisions of a scientific nature. However, the scientific understanding required for some decisions, for example whether mobile phone masts should be sited near schools, may be beyond the capabilities of non-scientists. So it is the skills of scientific reasoning that need to be developed so that the skills can be used effectively in different contexts. In order for children to understand what scientific reasoning is they will require opportunities to practise such skills. It has been argued in this thesis, that such skills can be developed through argumentation, where children are faced with decisions to be made where the evidence might be inconclusive. The decisions should engage the children in discussions so that learn to deal with alternative opinions and become skilled at making justified claims and counter claims.

In chapter 3, the case was advanced for science education to develop children's skills of argumentation. The research has shown that, given suitable activities, children can argue and reason to come to a conclusion that they can justify. It has been concluded that science education has a particular role to play in developing children's skills in using evidence to justify claims and decisions because the children should be engaged in investigations that require them to collect data from which they should be able to draw justifiable conclusions. In addition, children can be taught about the nature of scientific evidence, as Wellington and Osborne explain

> Constructing an argument for any piece of scientific knowledge requires the use of evidence and the consideration of counter arguments.
> (Wellington and Osborne 2001: 73).

Sang (2002) argues that children need to appreciate that, when evidence is limited, scientists may find it hard to untangle the causes of a particular outcome, especially when there is no well-established explanation linking causes and outcomes.

However, it is difficult for children to appreciate uncertainty in scientific knowledge if they are *only* taught about well-established scientific facts and given investigations to do where the answers are already well known. This study has shown that children, aged ten to eleven years old, are capable of sustained argumentation and that perhaps some primary school teachers underestimate the capabilities of children of this age. The study has revealed that where argumentation has been less advanced, few of the children engage in opposition or demand evidence for counter claims. Some of the groups worked together in a way that avoided arguments, resulting in a quarrel, but in so doing, also avoided arguments, that result in the evaluation of evidence and the justification of choice. If teachers were to teach the skills of using evidence more overtly perhaps more children would develop the scientific reasoning skills whereby the links between evidence and claims can be examined and learn how to judge whether one argument is better than another.

Skills used in experimental work, specifically those of using evidence, can be developed through work that does not involve the use of apparatus (Roberts and Gott 2002; Osborne 2002b). The findings of this research support this view as the activities show that when children are called on to explain their ideas and justify their claims, their use of evidence and their ability to draw conclusions are exposed. Teachers can use such activities to foster argumentation skills and respond formatively to children to develop their reasoning. How teachers can use scientific activities to facilitate discussions is now considered.

9.5.2 Teaching investigative skills in science through group discussions

As discussed in chapter 3, the introduction of the National Curriculum has resulted in more whole-class teaching and less group work in the primary classroom and pupils spend a lot of time 'writing things down' in science lessons. (Pollard et al. 2000).

Yet, group discussion of evidence can help children see the strengths or weaknesses of their decisions as the activities developed for this study demonstrate. The activities presented the children with choices and decisions that were not obvious and in some groups the children took different views and made different decisions. For example, one activity asked the children to decide how to deal with bats inhabiting a roof space. Before they had read the evidence, some children chose to capture or kill the bats. In most cases, these plans were adapted or changed when the evidence revealed that it is against the law to hurt bats and people could be fined £2000 for killing a bat. In the interviews, the children gave reasons for the change in plan; these varied from wanting to avoid moving the bats when they were roosting (Simon of the Castle Hill Group) to not wanting to be fined so 'we could spend it all going shopping' (Chantal of Woodstreet Junior Group 2). Only one child did not change her plan that would involve breaking the law; Amy's idea, before she read the evidence, was to put poison down to kill the bats and after the discussion she saw no reason why she should change her mind. Whatever the motivations behind the choices, all the activities used in this study gave children the opportunity to draw on evidence to support a particular claim or make a counter claim.

However, as the findings have shown, not all children demonstrated the same level of skills in the use of evidence. It is proposed, therefore, that children could be taught to evaluate evidence in science activities, both in practical and in non-practical situations. The findings of this study suggest that children demonstrated the same skills in the use of evidence, whether the evidence was a set of results from a practical or the evidence was presented as written factual information and pictures. As argued in chapter 2, to appreciate some of the concepts they will face as adults of the future, children should be taught how to weigh up evidence and make decisions about issues that affect their own and other people's lives. It is only the future scientists that would be involved in evaluating data that they had collected themselves. Therefore, teachers could develop children's skills in interpreting and evaluating evidence in different contexts. For example, as well as children interpreting the data they have recorded from an investigation, they could also be given activities where they interpret and evaluate evidence from secondary sources.

In chapter 7, it was suggested that to begin to develop children's skills in argumentation, tasks that gave the children limited options were better than open-ended tasks. Where alternative choices were provided children had something to argue about.

Where they had to put forward their own choices, the argumentation was weaker. Teachers could use decision-makings tasks where, for example, children are given some data from an experiment and they have to choose the best explanation for these results from three different alternative explanations. More open ended decision-making tasks, where the children are expected to provide different explanations, could be used once.

The transcripts suggest that the Castle Hill Group might have been taught about the processes of discussion and how to oppose each other's views in a constructive way. They took each other's ideas and discussed each one systematically, considering the merits of each one. This finding is only tentative and but there is support for the idea of teaching children about how to discuss in groups in the literature as is discussed more fully in the next section.

9.5.3 Teaching children how to work in groups

Harwood (1995) suggests that many young children already possess the beginnings of the basic skills needed for discussion and decision-making but that they are often not aware of how and when to use them. He believes that teachers should emphasise group and communication skills, such as listening, questioning, challenging and giving explanations and evidence. Harwood is very clear that teachers have a specific role to play in teaching children about working collaboratively. Although the research reported in this thesis suggests that the teacher has influenced the way children work together, the role of the teacher was not a focus of this research and so this finding is tentative and requires further investigation before firm conclusions can be drawn.

It is possible that more able children are able to utilise their skills better in a group context whereas, less able children may have the skills but are unaware of how to use them in the group context. Mercer (1996) believes that children over ten years of age may have all the language strategies they need to engage in exploratory talk, but they might not be aware of how best to use these strategies to go about learning together in the classroom. This research supports this view, as the data show that all the children could justify their claims in the individual interviews but some only when they were prompted to do so. These findings suggest children understand *how* claims can be justified but not the reasons *why* they need to be justified.

Herrenkohl et al. (1999) found in their study of children's discussions that some children aged eight to ten years old, despite being given the opportunity to question and challenge their peers, do not do so. The focus of Herrenkohl et al.'s study was the value of scaffolding student discussions and their study revealed that children could be helped to engage in sophisticated conversation. However, in order to do so, the children required explicit guidance on which roles to take to monitor their own and their peers' thinking. Therefore, it would seem that, as Herrenkohl et al. suggest, children could benefit from explicit guidance on strategies to use when working in a group.

This study proposes that children would need to understand the consequences of the roles they take in order to appreciate the contribution they, as an individual, can make to the group's discussion. They need to see that working in a group is not just a question of taking it in turns to say what each person thinks about an issue, but is about how they respond to each other's ideas and engage in thinking and reasoning together.

Once children can appreciate the different roles they can adopt in a group it may be possible to select groups to achieve a balance of roles to avoid children taking on similar roles as was seen in this research. Also if they appreciate the importance of taking on positive roles within a group, then children may not adopt the negative roles witnessed in this research.

It is evident from the findings from this research that the group comprising the widest range of positive roles, worked more collaboratively together, but that it is not just the range of roles that is important. It would appear that some roles are more significant to the success of the group than others.

9.5.4 Significant roles in group work

To understand why groups worked in different ways, the analysis drew on the work of Belbin (1981) and his study of successful management teams. The analysis showed that much of Belbin's theories as to why some teams succeed and why some teams fail, appear to apply to the groups of children observed in this research. He describes that the most positive indicators of a successful business team are the:

> attributes of the person in the Chair, the existence of a good Plant, a spread of mental abilities, a spread also in personal attributes laying the foundations for different team-role capabilities, a distribution in the responsibilities of members to match their different capabilities, and finally, an adjustment to the realization of imbalance.
>
> (Belbin 1981: 90)

As described in chapter 8, nine roles have been identified to describe the behaviours of the children involved in the activities in this research. These roles were derived from Belbin's work from adult teams, and also from studies that identified roles children adopt in schools (Richmond and Striley 1996; Hogan 1999). The roles children adopted in this study were identified as both positive and negative influences on the success of the team. However, like Belbin's teams, the most positive indicators of a successful group of children can be attributed to the contributions of particular roles.

The Chair asked other group members to contribute to the discussions and organises the way evidence is discussed. This role appeared to be important in guiding the way the group worked together and the way argument was sustained throughout the discussions. Another key role apparent in the children's discussions was the Information Manager.

The Information Manager ensured that the given evidence was not ignored and that, when necessary, the evidence was revisited before final decisions were made. The successful group also included a Promoter of Ideas who made suggestions that the group could discuss. Sometimes these ideas were inappropriate but in discussing these ideas the groups came to a better understanding of the possible choices available to them.

Finally, a group comprising children who were prepared to take part in the discussion, the Influential Contributors, were a positive influence on the group. However, it appears from this research that it is the combination of the roles that affects the way evidence is used and the process of argumentation; the most successful groups included a Chair, an Information Manager, a Promoter of Ideas and all four children were Influential Contributors.

These findings support further the recommendation that children should be taught about the importance of the various roles they can take in a group. Possibly, if they could identify the natural role they take, then they would be in a position to adjust their roles to that of the requirements of their group. In this way, groups have the possibility of developing and improving the way they work together. These suggestions have important implications for teachers and will be discussed in the following sections.

9.6 Implications for teachers and their professional development

These findings have implications for teachers in three main areas. These areas concern the way children are taught about:

- using evidence in science;
- the skills of argumentation;
- group dynamics.

9.6.1 Using evidence in science

Ways need to be found so that primary schools teachers can develop their pedagogic practices in order to enhance the children's skills in using evidence to justify their claims, particularly the claims they make in conclusions to scientific investigations.

The skills of considering and using evidence is becoming more overt in the teaching of science at Key Stage 3 (DfES 2002), but these skills are not yet a key issue in the primary school. Part of the problem here arises because the focus for many scientific investigations is the development of a 'fair test' rather than on the interpretation of the evidence obtained (Watson et al. 2000) or making a particular phenomenon happen (Leach 1999). Therefore, there is less emphasis on the interpretation of inconclusive or conflicting evidence.

Also of concern, is the way teachers respond to questions put to their classes. Both correct and incorrect answers need justification and exemplification as, in both cases, the child's thinking behind the answers needs exposure. Explanations to show what evidence the child has used in coming to an answer will show if the reasoning was sound; for the incorrect answer it may highlight where there are misconceptions or misunderstandings.

For teachers to develop new practice they need to have a good understanding of the underlying theory (Adey 2002). Professional development programmes need to include the development of teachers' own understanding of the use of evidence in order that they can plan activities that encourage children to question and demand justification for claims made by each other.

Activities used in the classroom should also include the analysis of data for which there is not a definite answer to be found or where children are presented with conflicting evidence. In this way children will begin to learn about how evidence needs to be evaluated, what weight can be placed on different sources of evidence and what might be wrong or inconclusive about the evidence they are examining.

Teachers also need to consider the value of letting children carry out science investigations where the answer may not be found or where the teacher is unsure of what the outcome might be. By carrying out activities where they are genuinely 'investigating', children will learn more about the nature of scientific enquiry instead of perceiving that carrying out investigations is just a matter of following a set procedure. If, as suggested by Watson et al. (2004), current practice in schools assumes that carrying out scientific enquiry requires a set procedure carried out by individuals, then the opportunities to work in groups will be reduced and children will not experience having their ideas challenged by their peers. Watson et al. argue that students need to appreciate the process of argumentation in order that they can employ the procedures of scientific inquiry effectively. Therefore, children will need to be able to work in groups where they are expected to resolve conflicts in ideas and reach conclusions that they can justify to each other.

9.6.2 Teaching about argumentation

In chapter 2 it was ascertained that children should have the opportunity to develop their reasoning skills and their ability to consider the significance of evidence. It was considered that the development of children's thinking and reasoning skills should be more overtly addressed in the classroom through the teaching of argumentation.

Quinn makes a compelling case for children to be taught to reason, to be able to see the weaknesses in arguments and to able 'to stand up to authority figures ...with a respect for reason and argument' (Quinn 1977: 5). He reproaches teachers for not having tried to develop these skills in schools and expresses his disappointment with the National Curriculum and its lack of attention to the development of argumentation skills. This research would reiterate this lost opportunity to develop the skills of argumentation, particularly in the science curriculum. If the skills of argumentation that children do develop are not part of a planned process, then for some, or many primary school children (this research is unable to say), these skills are being neglected.

As studies show that the skills of argumentation can be enhanced in the classroom (Driver et al. 2000), opportunities are being missed in some schools to develop these skills. It is important that primary teachers are made aware of the range of abilities they might expect in children at Key Stage 2, in order that they can plan for progression in skill development. There are studies being carried out in secondary schools in this area, for example the Ideas, Evidence and Argument in Science project (IDEAS) (Osborne et al. 2004), and it is proposed that primary teachers also need be involved so that continuity can be maintained across the key stages.

Teaching children to argue is most likely to be developed through group work as it is not easy for children to question their own claims or challenge an interpretation of evidence. The final implication for teaching raised by this study is how groups can be taught to work effectively together.

9.6.3 Children's understanding of the roles they adopt

If primary teachers were to be expected to teach children about the effects of different roles on the success of a group, then they will require professional development programmes to support them in making changes to their approach to teaching children about working in groups. Teachers, themselves, need to aware of how the different roles group members adopt affect the success or failure of the group. They will also need to have ways of identifying the roles children favour. Only then does it become possible to find the optimum combination of groups of children in the classroom.

9.7 Limitations of this research and suggested modifications

This research has based its findings of observations of small groups of children discussing different issues as autonomous groups. Due to technical reasons these observations took place outside the classroom away from the normal class situation but, as was explained in chapter 5, the unusual venue for the group did not appear to affect the children's behaviour.

All the groups comprised children, aged between ten to eleven years old, but the literature discussed in this chapter refers to studies involving children of different ages, both younger and older children. Had the behaviours of the children recorded in this study been very different to those noted in these other studies, then the results might not be representative of children aged ten to eleven years old. However, this was not the case suggesting that the different ways children work together in a group noted in this research are typical of this age group. It should be noted that, because of the nature of the activities, non-readers were not included in the sample.

Other authors (Bennett and Cass 1989; Jarvis 1993; Murphy 2000) have reported on the unequal contribution of girls and boys to discussion and group work, and while the data from this research project could have been analysed to see if the gender difference was significant, the research method was not designed for this purpose and therefore, such analysis, would not be appropriate.

There are always lessons to be learned about the research methods chosen after the data collection is complete despite pilot studies being carried out to identify possible amendments. Although it is important to recognise the limitations this study it is also important to stress that these limitations do not weaken the strength of the findings, rather they highlight where further research will be required.

Details of suggested improvements are given below with an explanation as to how these changes would have enhanced the study. These improvements relate to:

- identifying the roles;
- the type of research activities;
- observations of the children;
- observations of the teacher.

9.7.1 Identifying the roles

Analysis of the data reveals that children take on different roles in the discussions. The characteristics used to define the roles have been based on observations of the behaviours of the children in the groups. As discussed earlier, Belbin (1981) was able to assign his role definitions using the personalities of the team members, as well as the characteristics they displayed in the team activities. Thus, he was able to provide a comprehensive picture of the type of people that would be useful to have in a team. In hindsight, it would have been helpful to find out more details about the personalities of children and so a more complete study could have been made of the role definitions for children working in groups. The clearer the role definitions are, the more value they have for teachers in assigning the roles to the children in their classes.

9.7.2 The type of research activities

The activities described in chapter 5 were very successful in facilitating discussion in nearly all the groups but in some groups the discussion was very limited. The instructions given to the children indicated that they did not need to reach a consensus for their decisions and this might account for the differences in the group discussions. Had the children been required to reach a consensus, this may have led to further challenges, more opposition and therefore greater use of evidence as the children had to defend the claims they had made. Watson et al. describe the essence of scientific inquiry as:

> the thinking that enables the scientist to make claims supported by empirical data and to use these to develop explanations and theories.
>
> (Watson et al. 2004: 25)

Activities where children work on scientific decision-making in small groups provide opportunities for them to discuss evidence and explain their own points of view. As discussed earlier, the activities used in this research did enable children to use the evidence to support different viewpoints. At the outset of the research it was felt that the expectation that the group had to agree on a choice might cause unnecessary conflict for children working in unfamiliar conditions. In hindsight, it might have been possible to require the group to agree a decision in the later activities, as the children became more familiar working in their groups with the researcher.

9.7.3 Observation of the children

Another issue that requires exploring further is to what extent the findings represent the 'natural' behaviours of the children involved. If the behaviour observed was atypical of many of the children, this would limit the value of the conclusions that have been drawn.

To enable comparisons to be made between the behaviour of the children in the whole class situation and when they had been working in groups, observations were made of the children in the whole class situation. Such observations were only possible for four of the groups as the class teacher of the Castle Hill Group did not want the whole class to be observed. However, discussions also took place with all the class teachers to check that the behaviours recorded on the videotape were representative of how the children behaved in the normal class situation. In all but one case, the observations and discussion with the teachers confirmed that the behaviour of the children in the research activities was in character with their behaviour in class. The class teacher of the Woodstreet Junior Group 2 reported that Chantal was more assertive in the group discussions and she spoke more fully about her ideas than she did in the whole class situation.

Pontecorvo and Giradet (1993) suggest that the discourse of children working autonomously in their groups demonstrated higher ability than when they were guided by the teacher. For the research reported in this thesis, further observations of the children working in groups in other subjects, and working with groups with a teacher input, would be required to say whether the children would perform differently with teacher guidance. As it is, this study cannot confirm Pontecorvo and Giradet's findings.

Nevertheless, the observations of the children's behaviour in this research have led to some valid conclusions about the way children aged ten to eleven years old do expose their thinking when working autonomously. The transcripts show that children are able to reason and can provide justification for their decisions but some may need prompting to do so. The research has also shown that when children discuss scientific evidence without teacher intervention, roles adopted by the children in the group activity, can influence the ways children explain what evidence supports their claim. For example, where there was a Chair in a group, children were encouraged to explain their choices, to justify this choice and to consider alternative ideas.

However, the findings show that not all children demonstrate the same level of skill and that there are considerable differences between the skills of children of the same age. One factor that might account for these differences might be the approach adopted by the teacher as is now discussed.

9.7.4 Observation of the teachers

Wall (2002) suggests that the interactions, both verbal and non-verbal, children demonstrate when working in groups are being learnt by the pupils through 'imitative modelling' indicating that the teacher has a key role in developing such skills in the children. Children taught by teachers who model how to provide justification for claims or ask others to justify their claims, may behave differently where no such expectations have been raised or have even been discussed.

The findings show that the children, in this research, all practised some of the behaviours required for group work i.e. they allowed each other to read out the information sheets, they took it turns to speak and they listened to the members of the group. Yet, some groups had more sophisticated interactions; children in the Castle Hill Group would negotiate who was going to speak and when a child was interrupted they would go back to that child and ask them to continue.

More observation of the class teacher working with both the whole class and with groups of children would help identify whether the ways the children work together as a group had been influenced by the overt teaching of *group behaviour*.

9.8 Suggestions for further research

Given below are several questions arising from the findings of this research that suggest further investigation. The first question concerns the way children should be taught about the use of evidence in making decisions. Subsequent questions concern the ways children work in groups, arising from the suggestions from Belbin's study into what makes successful teams. Although there is much research about how children work in groups (Gayford 1993; Jarvis 1993; Ratcliffe 1996; Hogan 1999; Wall 2002) there is little research into assessing the effects of the natural roles children adopt and how these roles affect the quality of group work. Answers to these questions should help teachers select the composition of the groups to bring about more effective discussion and argumentation in the primary classroom.

9.8.1 How can children's use of scientific evidence be developed?

At the time of writing changes are awaited with the new science National Curriculum due in 2005. In order that any proposed developments in science teaching are seen to be acceptable to teachers, the activities need to complement existing activities, rather than to be an additional requirement. The activities should also be seen to develop the skills that, at present, appear to be neglected.

Activities that encourage children to argue are already being developed for secondary school pupils (Simon et al. 2003; Osborne et al. 2004) and perhaps such projects could be extended to include the primary age range. The findings of the research reported in this thesis clearly show that children can argue and can use evidence to justify their claims. Extending successful initiatives from secondary schools to primary schools is already underway, for example the CASE project, initially developed for Key Stage 3, has been developed for Key Stages 1 and 2 (Adey and Shayer 2002). Perhaps the same developments will be seen for the argument projects now being developed in secondary schools.

The findings also illuminate a weakness of the children's argumentation skills in that they are reluctant to oppose each other's claims and there was a lack of counter arguments in the discussions. Children need to experience conflict in viewpoints so they can learn how to resolve such issues. They need to appreciate that a change of mind may be a strength in their thinking rather than a weakness. They also need to learn that sometimes agreements may not always be possible and that different interpretations may well have to be accepted.

Perhaps, if teachers were made more aware of the value of opposition in discussions (Simon et al. 2003) they might appreciate the need for children to experience opposition in a way that is not perceived as unfriendly or aggressive.

Teachers will require support to extend existing activities so that the development of children's argumentation skills and reasoning skills are maximised without any expectation of widespread change in their practice. Teachers will need to be aware of how these skills can be assessed in order that they can plan for the development of such skills. Some teachers may only need an awareness raised for them to see how their teaching can be developed, whilst for others it may require improving their confidence in handling conflicts in ideas. Further research is required to see how best teachers can be supported to change or adapt their pedagogic practice.

9.8.2 How can we identify children 'natural' roles in group work?

If we are going to select children to work in groups then we need a practical way in which teachers and, possibly the children, can identify the role they would naturally undertake. Belbin (1981) devised a Self Perception Inventory to give people a way of assessing their team roles. The inventory includes a set of statements respondents have to choose that best describe their behaviour. Each statement is allotted a number of points, indicating of which role this behaviour is characteristic. On completion, the inventory enables people to recognise the team role in which they can best contribute to the success of a team. It also can denote the back-up role a team member could adopt if the team did not require their primary role. Research is required to find out how such an inventory could be devised for children to recognise their 'best' role. Further research would also be required to check if all roles children adopt have been identified. This research cannot claim to have a definitive range of roles in the sample; research would have to be on a larger scale to see if further roles, others than those already identified, need to be included.

Research is required to develop techniques so that teachers and children can assess the team role they feel most suits the child. Once the roles have been assessed then perhaps teachers could select group that have a balance of roles rather than selcting groups on ability or friendship patterns. The findings of this research show that the group where there was a balance in roles, the Castle Hill Group, the group worked together more effectively; effective group work results in discussions where children do oppose each other's points of view, expect to give evidence to justify their claims and where they are prepared to weigh up evidence when considering all possible alternatives for the decision is made. Whether teachers can create balanced groups in their classes and how this balance would affect the group's effectiveness is now considered.

9.8.3 Can we create balanced groups in schools?

One of Belbin's principles for team design is that:

> personal qualities fit members for some team-roles while limiting the likelihood that they will succeed in others
>
> (Belbin 1981: 127).

Research is needed to find out which combinations of roles produced the most collaborative group work as teachers will need to include children who do not naturally work well with others. In business, workers who work best alone, would be unlikely employed where team work was an essential part of the of the job but in schools the teacher has little choice of which children are in the class. As the findings of this research showed that some children are reluctant to take part in discussions, research is also required to find out how to maximise the cooperation of children, who for example, may work more happily on their own. Cooperation might be improved by creating the 'right climate' for group work in the classroom as is now considered.

9.8.4 Can we establish the 'right climate' for group work to flourish?

Belbin explains that teams need to be well designed in order to be successful team members need to be selected on their different attributes. Where a team member does not complement the team, Belbin suggest the manager of the team seeks other colleagues who will provide the necessary balance within the team. But in schools the teacher has to include *all* children, whatever their role preference, in group activities.

Belbin explains that establishing the right climate in which teams can flourish is the foundation stone on which more effective teamwork in the future can be built. If we want to develop more effective group work in our classes then we must identify what is the right climate for groups of children to flourish. This climate can be created by the way the teacher works with the whole class and how different group combinations are managed in the classroom.

To understand how children can be encouraged to work together more effectively more research is required to find out what factors make one group more successful than another. This research has suggested that the range of roles is important and this needs further exploration. If the roles children prefer to take on when working in a group can be identified then different composition of groups by role could be explored.

9.8.5 What is the optimum range of ability for a group?

In many classes children work together in groups of similar ability. Even if the children choose their groups, this may well result in the same outcome as children's friendship groups may well comprise those of comparable abilities. If groups are to be selected to maximise the effectiveness of the group then we need to know whether the ability of the children needs to be taken into account.

Belbin found that a spread in mental abilities appeared to have a bearing on the company fortunes. He found that a team with a spread of mental abilities was able to pull together better than teams with intellectual homogeneity. The best results were associated with companies containing one very clever Plant, another clever member, and a Chairman who had slightly higher than average mental ability. Other members of the company were slightly below average. This formula was one that surprised Belbin, especially how having team members that of slightly lower mental ability could be an advantage to a team. His explanation was that in recognising there was a gap between themselves and the other more able members, competition was created between the less able members who then sought other ways of fulfilling themselves.

It would be very helpful for teachers to know if the same pattern would be found in groups of children. As explained above, Bennett and Cass (1989) carried out a study looking at the effect of group composition on the co-operative decision-making process. They worked with groups of three children that were homogeneous, (all high, all average, or all low attainers), groups that were heterogeneous (one high, one average, and one low attainer), and groups that were mixed (one high and two low or two high and one low attainer). Their findings show that the heterogeneous groups performed poorly whereas the mixed groups worked very well. The mixed groups, composed of one high attainer and two low attainers, performed much better than those composed of two high and one low attainer. The homogeneous group of high attainers consistently out-performed the groups of the homogeneous average and the homogeneous low attainers groups. High attainers performed well irrespective of the groups they were in.

The issues raised by both Belbin's work and Bennett and Cass's study contribute to the debate about grouping children by ability, whether in small groups or for a whole class situation. Opponents of mixed ability teaching have argued that more able children are held back by less able children, but if high attainers do well whatever the groupings, then this argument loses its credibility.

The findings from this research echoes Bennett and Cass's findings in that the high ability group consistently performed better that the other groups but further research is needed to make any other conclusions on the effect of ability groupings on the way children argue and use evidence in coming to decisions.

9.8.6 Can we improve existing groups?

In some classes the group work may already seem to be working successfully and a teacher might not see the value in breaking up the groups in the class. However, this does not mean to say there cannot be an improvement in the way the children work together.

Research is required to see whether children, who are made aware of the effects of the different roles on the success of the group, can identify where their particular skills are not being maximised. Belbin stresses the importance of team members finding jobs to do that fitted their personal characteristics and abilities; existing groups of children may find it helpful to redistribute some of the tasks they do, taking into account their natural role preferences. But to be able to redistribute roles, children will have to be able to recognise the strengths and weaknesses of the different roles they adopt. Research is needed to see if children are capable of understanding the contribution of different roles to the success of the group.

In many adult teams the most charismatic roles, the Plant and the Chair, are seen as having the most value; the Company Worker and the Completer Finisher less so. However, Belbin makes it clear that it is the *balance* of the team that contributes to its success. A positive effect of children studying the roles they adopt is that they might learn to value the contributions of children who take on the less charismatic roles, and in so doing, increase the self-esteem of these children. Increasing children's self esteem is likely to result in an increase in effectiveness of the group as well as the individual leaner. Research is needed to see if children's self esteem can be improved by an understanding of how successful groups work.

The above suggestions for research have focused on the way group work can be managed in the class to improve discussions. A key issue for this research is how discussions in science activities can be improved to develop children's scientific reasoning skills where evidence is evaluated and alternative choices considered. The implications of this study for primary science teaching are now considered.

9.9 Implications for the teaching of primary science

Primary science is important because it begins the process of the development of children's scientific reasoning skills, their ability to produce and understand scientific argument using reliable and agreed evidence to support conclusions (Millar and Osborne 1998). As discussed in chapter 3, the National Curriculum (DfEE 1999b) suggests that the development of scientific enquiry skills begins at Key Stage 1 with the collection of evidence and the ability to identify simple patterns in this evidence. At Key Stage 2 they should be able to consider evidence and to be able to make judgements about whether it can fully or partially support a claim. More developed reasoning involves recognising the limitations of evidence, and where it insufficient suggestions are made for further evidence to be obtained.

This research set out to discover how children make use of evidence in scientific decision-making activities when working in small groups. The findings have shown that children, aged ten to eleven years old, are capable of using evidence to make decisions but that some children need to be prompted to use evidence to question their own ideas and to justify their claims. The analysis has shown that where prompting took place, evidence was used more systematically and the level of argumentation was more sophisticated. Therefore, to develop children's scientific reasoning and their argumentation skills, interventions in discussion are required that prompt the children to justify their answers. In current practice, the teacher normally carries out prompting or scaffolding of children's discussions. But this research has shown that some children can drive the process of scaffolding the discussions themselves and thus they can work more independently of the teacher. If children do take on this role then group work could become more effective as teacher input could be directed where children are not yet capable of taking on this role for themselves.

As discussed in chapter 6, the children involved in this research demonstrate four levels of argumentation when discussing scientific activities. Each level describes the type of argumentation observed in the discussions. The data have illustrated that all groups were capable of reaching level 4A in at least one activity, where children discussed evidence that then led to the construction of arguments. However, only one group reached the highest level 4C where there was sustained argumentation observed in all activities. So although these levels might indicate the range of performance that children aged ten to eleven years old might be expected to demonstrate, more research would be required to find out what level the majority of children could reach at the end of Year 6. However, the levels identified for this research can provide the basis for making judgements about children's performance in the skills of argumentation at the end of Key Stage 2.

An important message from the findings of this research is that if teachers were to provide children with activities where scientific evidence is discussed and if children were taught to adopt the roles that maximise the use of evidence and argumentation skills, children's scientific reasoning skills and their understanding of scientific concepts could be enhanced.

Summary

The findings of the research have been documented and discussed in the light of existing literature and the importance of these findings, to science educators and teachers in particular, has been identified.

It is clear that allowing children to work in groups without teacher intervention has been a successful way of assessing the way children discuss and use evidence in coming to decisions. A key point that emerged during this study is that the success of a group of children, just like adult teams, is dependent on the roles the different group members adopt. Reflections on the composition of groups include not just the range of roles but also how the ability of the children needs to be taken into account when the groups are selected.

Suggestions, based on the findings, have been made for how the effectiveness of group work can be improved. Some of these suggestions are tentative and where this is so, further research has been recommended to investigate the validity of the suggestions made.

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Appendices 1-10

Appendix 1: Visits to Schools

1. Visits to pilot study schools

St Matthew's Primary School	Year	Topic	Date
Tom,Kristy,Badri,Rick	5	shoe	25.1.99 & 27.1.99
Tom,Kristy,Badri,Rick	5	bats	27.4.99
Sally, Pat, Tim, Josh	6	electricity	2.2.99
Kelly, Connor, Darren; Sharma	6	bats	9.2.99
Kelly, Connor, Darren; Sharma	6	cups	16.3.99 & 18.3.99
Sean,Sam,Katrina,Louise	6	bats	2.3.99
Sean,Sam,Katrina,Louise	6	cups	16.3.99 & 19.3.99
Harry,Emma,Kay,Richard	5	bats	15.4.99
Harry,Emma,Kay,Richard	5	coins	24.5.99
David	6	bats	2.3.99
Steven	6	bats	9.3.99
Mary & Linden	6	bats	9.3.99
Hayley & Simon	6	bats	9.3.99

Aston Primary School	Year	Topic	Date
Elisa and Neil	6	Pulse rate	29.1.99 & 10.2.99

Samuel Street Junior School	Year	Topic	Date
Emily, Peter, Jackie, John	6	Gerbils	14.7.99
Emily, Peter, Jackie, John	6	Cups	14.7.99
Anthony, Jeremy, Tad	6	Gerbils	13.7.99
Stuart, Kylie, Janet, Sammy	6	Gerbils	13.7.99
Stuart, Kylie, Janet, Sammy	6	Cups	16.7.99
Timothy, Charlotte, Marion, Jack	6	Gerbils	14.7.99
Timothy, Charlotte, Marion, Jack	6	Cups	16.7.99
Clare, Anna, Matthew, Patrick	6	Cups	14.7.99

Tindall Primary School	Year	Topic	Date
Ghi-Hyun, Morgan, Tim, Cassie	6	Marble	29.2.00
Jade, Zaynab, Wai Keung, Joshua	6	Marble	29.2.00

2. Visits to Main Study school

	Date	Activity	Trans	School	Time for activity in minutes
		1			
1	13 Oct 1999	Gerbils	22	St Anne's; Wandsworth	4
2	13 Oct 1999	Gerbils	23	St Anne's; Wandsworth	4
3	14 Oct 1999	Gerbils	24	Castle Hill; Oxshott	11
4	20 Oct 1999	Gerbils	25	Woodstreet Junior; Lambeth	13
5	20 Oct 1999	Gerbils	26	Woodstreet Junior; Lambeth	3
		2			
6	19 Nov1999	Cups	27	St Anne's; Wandsworth	4
7	19 Nov1999	Cups	28	St Anne's; Wandsworth	4
8	13 Jan 2000	Cups	29	Castle Hill; Oxshott	11
9	2 Feb 2000	Cups	30	Woodstreet Junior; Lambeth	1
10	1 Dec 1999	Cups	31	Woodstreet Junior; Lambeth	41
		3			
11	9 Feb 2000	Bats	32	St Anne's; Wandsworth	15
12	9 Feb 2000	Bats	33	St Anne's; Wandsworth	11
13	10 Feb 2000	Bats	34	Castle Hill; Oxshott	14
14	30 Mar2000	Bats	35	Woodstreet Junior; Lambeth	8
15	13 Apr 2000	Bats	36	Woodstreet Junior; Lambeth	17
		4			
16	4 Apr 2000	Marble	37	St Anne's; Wandsworth	19
17	13 Apr 2000	Marble	38	St Anne's; Wandsworth	8
18	16 Mar2000	Marble	39	Castle Hill; Oxshott	14
19	30 Mar2000	Marble	40	Woodstreet Junior; Lambeth	9
20	13 Apr 2000	Marble	41	Woodstreet Junior; Lambeth	11

Appendix 2: Pilot Study Activities

1. Shoes Activity
The Shoes Activity was an investigation to compare the friction of the soles of different shoes. This activity was led by the teacher in the classroom and was part of the normal teaching programme. The topic of the lesson was *Friction* and the children carried out an investigation titled *Which shoe exerts the greatest friction?* The children were provided with a board and a pile of books to make a slope. They provided their own shoes to test and had to devise their own method.

2. Pulse Rate Activity
The class teacher organised a discussion on how to set up an investigation that would record the effect exercise had on pulse rates. For 15 minutes the children practised timing their own pulse rates and then took their resting pulse rate, then they went outside in the playground to record their pulse rate after exercise. Two children, Elisa and Neil, were observed but at the end of the lesson they had not finished collecting all the required data. So some data on pulse rates was prepared for them to examine on the next visit. These data contained some anomalous, as the pulse rates given for a child after 1 minute of exercise were almost exactly the same as for after 10 minutes of exercise. Elisa and Neil were interviewed separately about this data and they both recognised the anomalies in the data.

3. Electricity Activity
The children made circuits with batteries, wires and bulbs, following the instructions of the teacher. They investigated the brightness of the bulbs with different numbers of batteries.

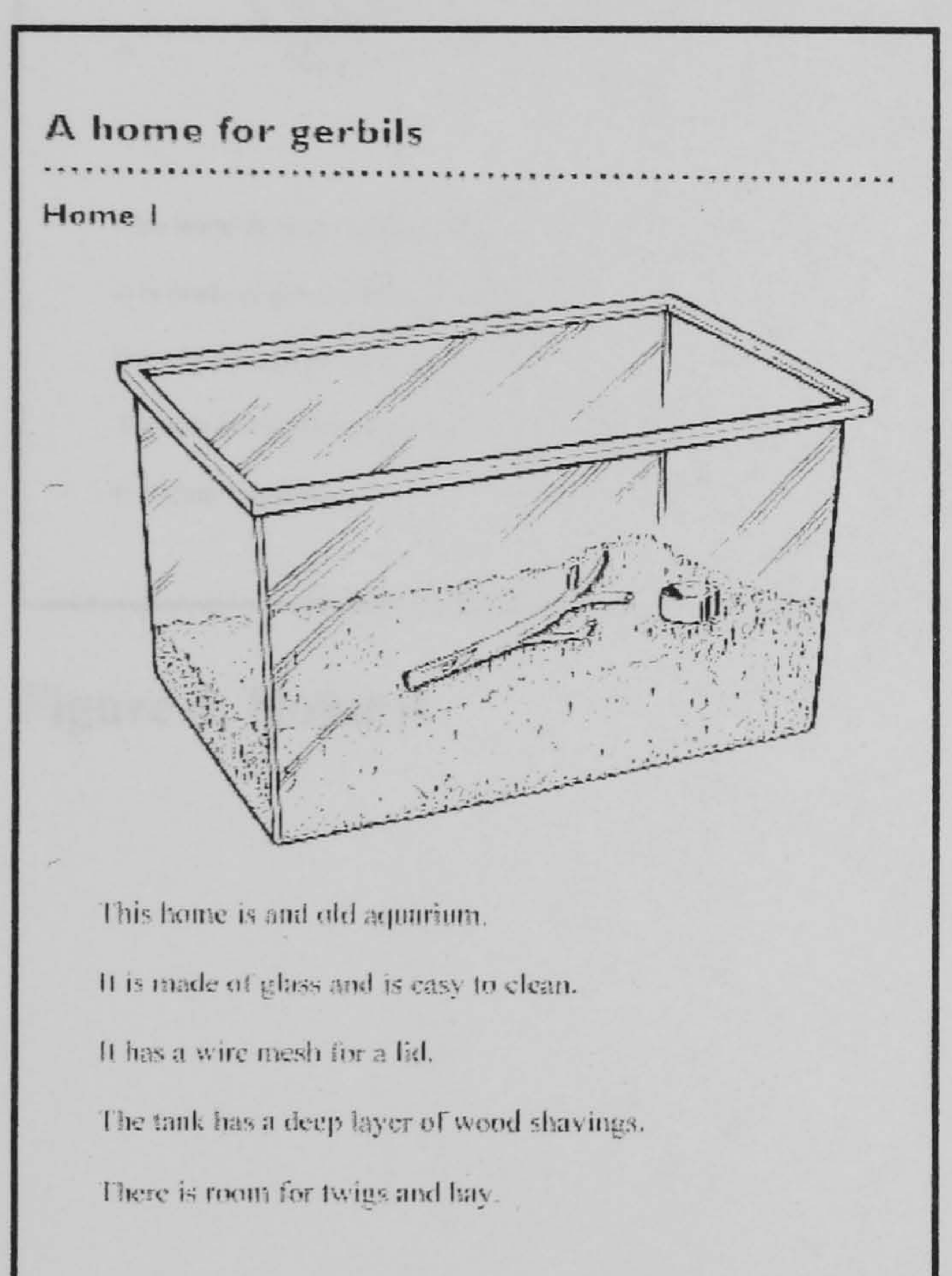
4. Coins Activity
This activity was carried to see if investigating the magnetic properties of coins provided another appropriate activity in a scientific context.
In the Coins activity the teacher introduced the lesson to the whole class. The title of the investigation was *To investigate the magnetism of 1p and 2p coins.* The children emptied the coins onto the table and they were asked to pick up the coins and test them to see if they were magnetic.

Details for the Gerbils, Bats, Cups and Marbles are provided overleaf.

Appendix 2: Information for Gerbil home activity used in the pilot study

Home for Gerbils Activity

The children had to choose a home for some gerbils to be kept in their classroom.


A home for gerbils

Home 1

This home is and old aquarium.

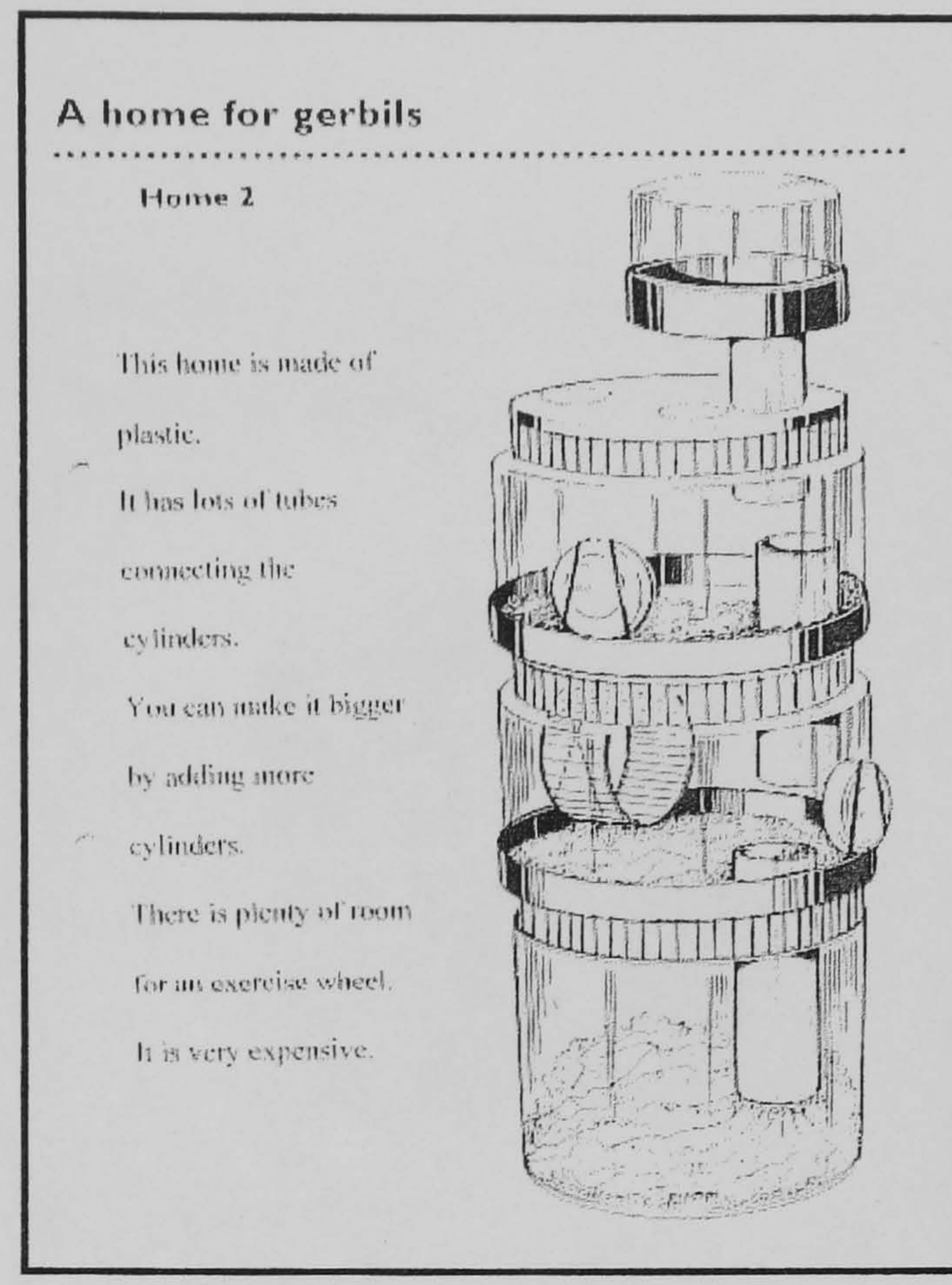
It is made of glass and is easy to clean.

It has a wire mesh for a lid.

The tank has a deep layer of wood shavings.

There is room for twigs and hay.

Figure 1. Home 1


A home for gerbils

Home 2

This home is made of plastic.

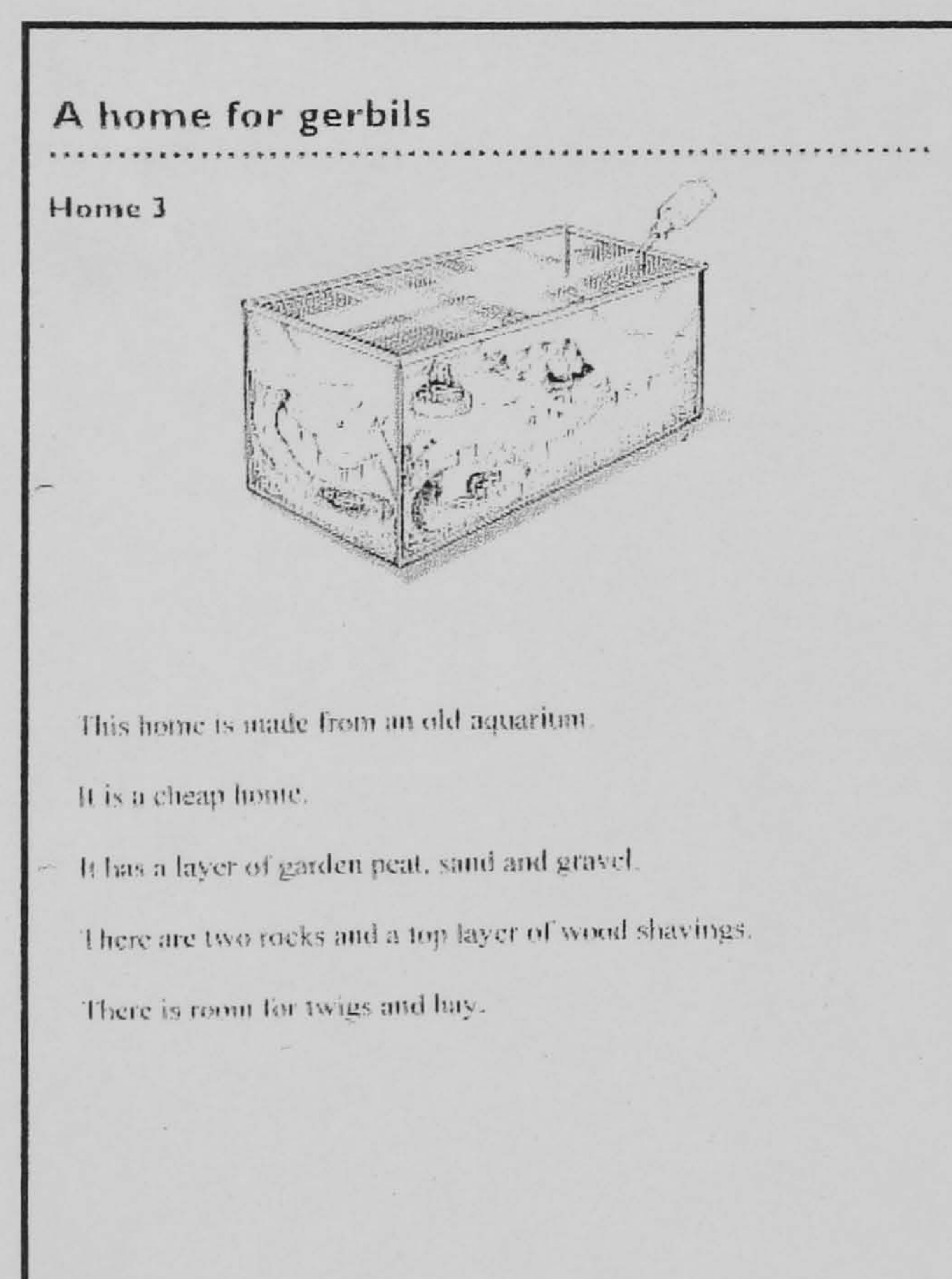
It has lots of tubes connecting the cylinders.

You can make it bigger by adding more cylinders.

There is plenty of room for an exercise wheel.

It is very expensive.

Figure 2. Home


A home for gerbils

Home 3

This home is made from an old aquarium.

It is a cheap home.

It has a layer of garden peat, sand and gravel.

There are two rocks and a top layer of wood shavings.

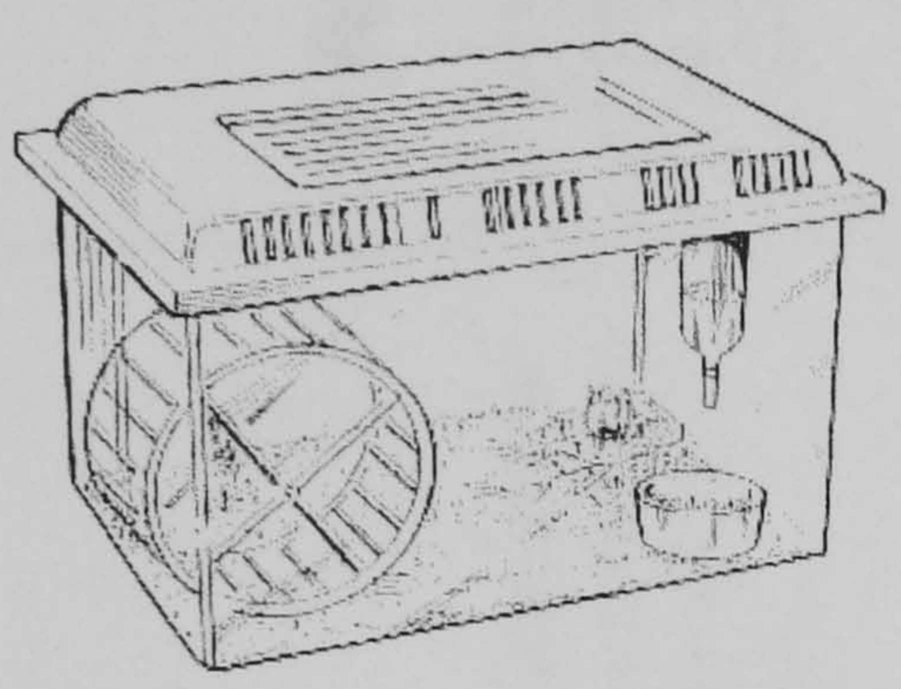
There is room for twigs and hay.

Figure 3. Home 3

Appendix 2cont: Information for the Gerbil Home activity used in the pilot study

A home for gerbils

Home 4



This home is made for hamsters.

It is made of plastic with a plastic roof.

It is big enough for one gerbil.

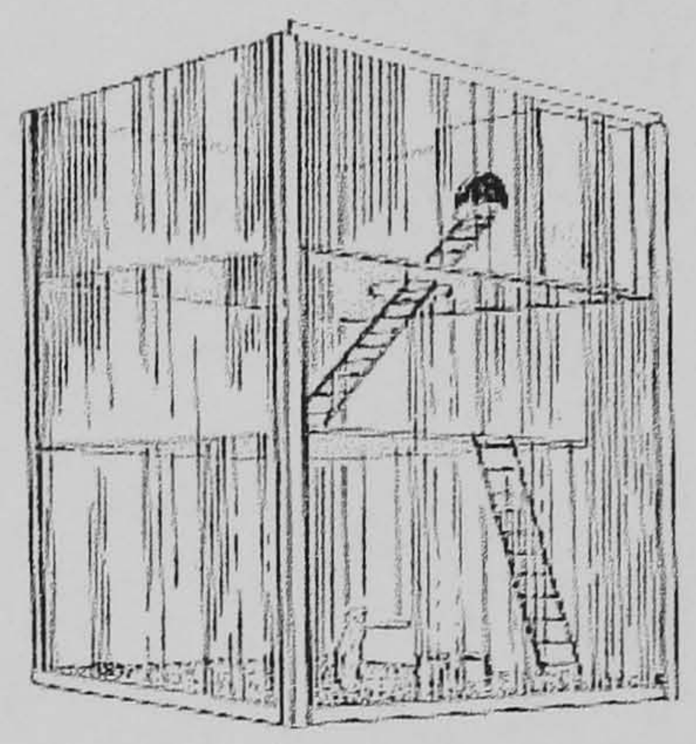
There is an exercise wheel and a plastic food bowl.

It is quite expensive.

Figure 4. Home 4

A home for gerbils

Home 5



This home has metal ladders.

The tray at the bottom of the cage is plastic.

The tray is not very deep.

There is plenty of space for an exercise wheel.

The box at the top is made of wood.

Figure 5. Home 5

Bat facts

BAT FACT?
Bats are only found in old buildings.

FALSE!
Britain's most common bat is the Pipistrelle and it prefers modern houses.

BAT FACT?
Bats can get tangled in your hair.

FALSE!
Bats use a system called echo-location to find their way in the dark. It works very well and they never fly into peoples' hair.

BAT FACT?
Bats carry diseases.

TRUE!
All animals carry diseases but there is no evidence that bats carry any which people or their pets can catch.

BAT FACT?
A bats drink blood.

FALSE!
There are only three species of vampire bat (and they are only found in Central and South America).

BAT FACT?
Some people are very scared of bats.

TRUE!
However, this is usually because they do not know the truth about them.

BAT FACT?
Bats are blind.

FALSE!
Bats have quite good eyesight.

BAT FACT?
Bats breed quickly, like mice.

FALSE!
Mice have large numbers of young each year but bats only have one baby a year.

BAT FACT?
Bats are dirty.

FALSE!
Bats regularly wash and groom themselves to keep in peak condition for flying.

Bat facts

BAT FACT?

It is against the Law to kill a bat.

TRUE!

You can be fined up to £2000 for killing or even injuring a bat!

BAT FACT?

It is against the Law to sell a bat.

TRUE!

Even a dead one!

BAT FACT?

Bat droppings can be a nuisance.

TRUE!

They can make a mess of cars, windows, things stored in lofts, patios, etc.

BAT FACT?

Bats are a farmer's friend.

TRUE!

Bats in Britain feed only on insects. Some of the types they eat are pests which damage crops.

BAT FACT?

It is against the Law to posses a bat.

TRUE!

Even a dead one!

BAT FACT?

It is against the Law to disturb roosting bats.

TRUE!

Even if they are in your own house.

BAT FACT?

Bat urine can be a nuisance.

TRUE!

Although they only produce small amounts of urine, it can damage polished wooden surfaces. This is a common problem in churches.

BAT FACT?

Bats have a big appetite.

TRUE!

Some bats eat about 3000 insects each night. Flying uses a lot of energy!

Bat facts

BAT FACT? Bats are like birds.	**FALSE!** Bats are mammals like our selves.
BAT FACT? Once you have got bats in your house they will always be there.	**FALSE!** Bats do not use a roost all year round. In winter they hibernate in caves, old mines and hollow trees.
BAT FACT? Bats are endangered.	**FALSE!** The number of bats in Britain is declining rapidly. One hundred years ago there were ten times as many bats.
BAT FACT? Bats droppings are a health hazard.	**FALSE!** Bats droppings are very dry and only made up of the skeletons of insects.
BAT FACT? Bats are fragile.	**TRUE!** Their delicate wings are easily damaged. Many are killed by pesticides meant to kill insects and by some wood preservatives used in lofts.
BAT FACT? Bats only live for one or two years.	**FALSE!** Most species have a life span of 15-35 years!
BAT FACT? Bats can live just about any where.	**FALSE!** Most species of bat need special places to roost or hibernate. Bats are suffering because old barns are being converted, hollow trees chop-ped down and caves blocked up.
BAT FACT? Bats can damage your house.	**FALSE!** Bats' teeth are for eating insects, they are too small for gnawing through wood, brick or electricity cables. They get into houses through holes which are already there.

Appendix 2: Information used for the Cups Activity in the pilot study

Yr 6 Class **Names:** **Holly, Ashley, Jamie, Maria**

The children had to choose one of these cups to take on a picnic

Cup	Cost	Weight	What happened when the cup is hit by plasticine bob	What happened to the temperature of the water	What happened when a heavy book is put on the top of the cup
Thin Plastic	12p each	3g each	It gets knocked down easily	It rose 2 °C in 5 minutes	It gets squashed
Glass	85p each	250g each	It stayed up all the time	It rose 0 °C in 5 minutes	It stayed the same
Thick Plastic	25p each	10g each	It stayed up most of the time	It rose 1 °C in 5 minutes	It stayed the same

Marble Activity

The children were given the following accounts of a science investigation. They also had models of the tubes. Their task was to decide down which tube the marble would roll down faster.

Account 1: Winston and Katy

Investigation:
To find out in which tube the marble goes down the fastest

What we did:
We rested the bubble wrap tube on 6 books. We started the timer and let the marble go from the very top of the tube at the same time.

When it reached the bottom, we stopped the timer. We wrote down the time in our chart straight away. Then we did it 2 more times exactly the same.

Then we got the glue ridged tube and put it on the same pile of books in the same place. We rolled the marble down the tube 3 times just like the bubble wrap tube.

Results:

Tube	1st time (seconds)	2nd (seconds)	3rd (seconds)
Bubble wrap	6	5	6
Glue tube	3	3	3

Our results show that the marble rolls down the glue tube fastest. The bubble wrap slows down the marble because of all the little bumps.

Account 2: Hari

Investigation:
To find out in which tube the marble goes down the fastest

What we did:
We rested the glue tube on a pile of books. I rolled the marble down the tube and Rebecca timed how long it took to get to the bottom. We did it 2 more times. Then I wrote down the times.

Rebecca went and got some more books. I put the bubble wrap tube on them. We rolled the marble down 3 times and I wrote down the times it took.

Results:

Tube	1st time (seconds)	2nd (seconds)	3rd (seconds)
Bubble wrap	3	3	4
Glue tube	5	4	4

My results show that the marble rolls down the bubble wrap tube fastest.

Account 3: Rebecca

Investigation:
To find out in which tube the marble goes down the fastest

What we did:
We put the glue tube on a pile of books. Hari rolled the marble down the tube and I timed how long it took to get to the bottom. We did it 2 more times. Hari wrote down the times.

Then I got some more books from Winston and I put the bubble wrap tube on them. We rolled the marble down the tube 3 times and timed how long they took.

Hari wrote down times and I copied them later.

Results:

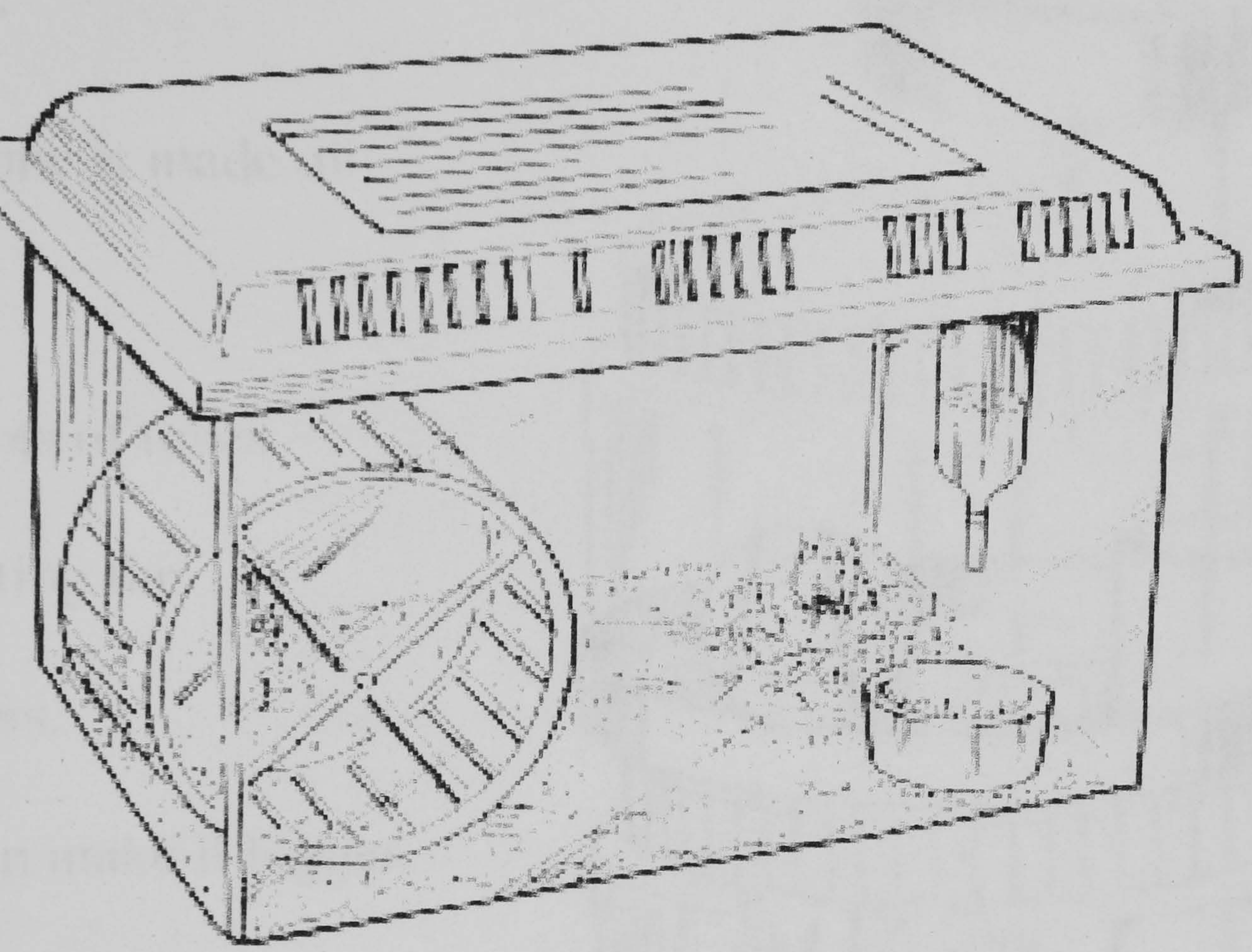
Tube	1st time (seconds)	2nd (seconds)	3rd (seconds)
Bubble wrap	3	3	4
Glue tube	5	4	4

The marble rolls down the glue tube fastest.

Appendix 3: Information for the gerbil homes activity used in the main study

A home for gerbils

Home 1



This home is made for hamsters.

It is made of plastic with a plastic roof.

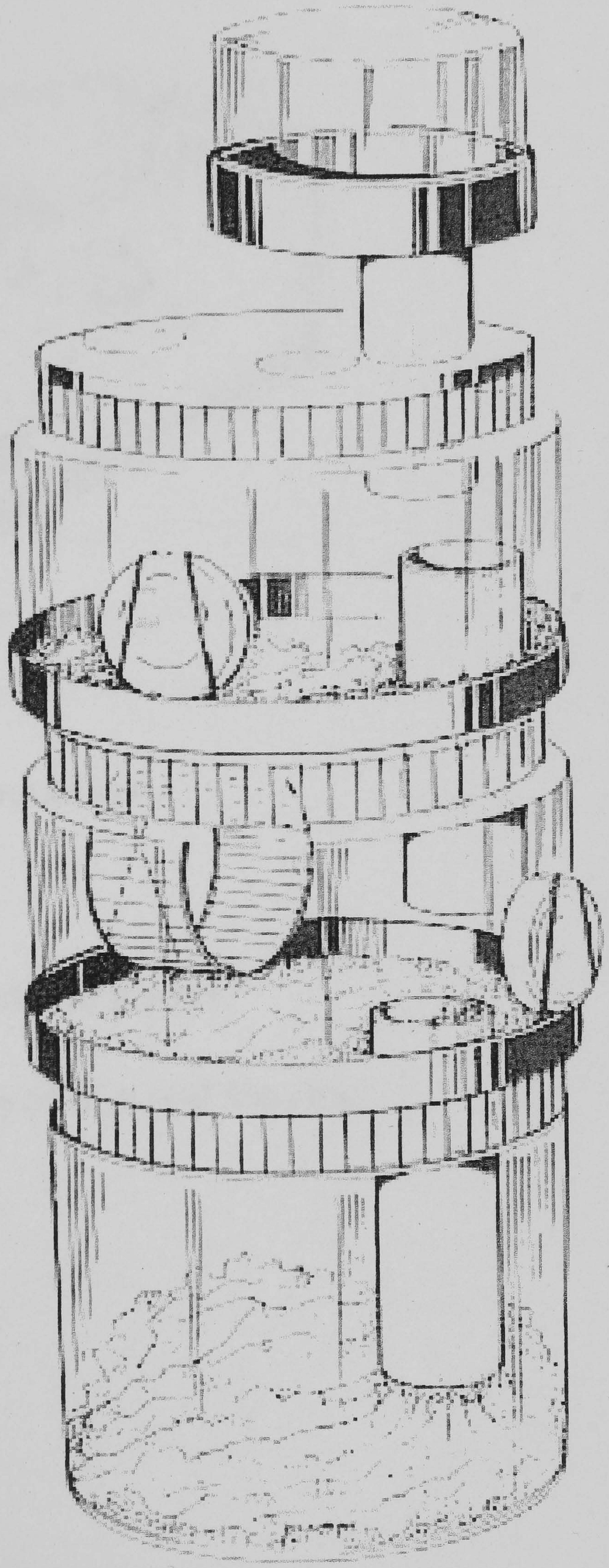
It is big enough for one gerbil.

There is an exercise wheel and a plastic food bowl.

It is quite expensive.

A home for gerbils

Home 2



This home is made of

plastic.

It has lots of tubes

connecting the

cylinders.

You can make it bigger

by adding more

cylinders.

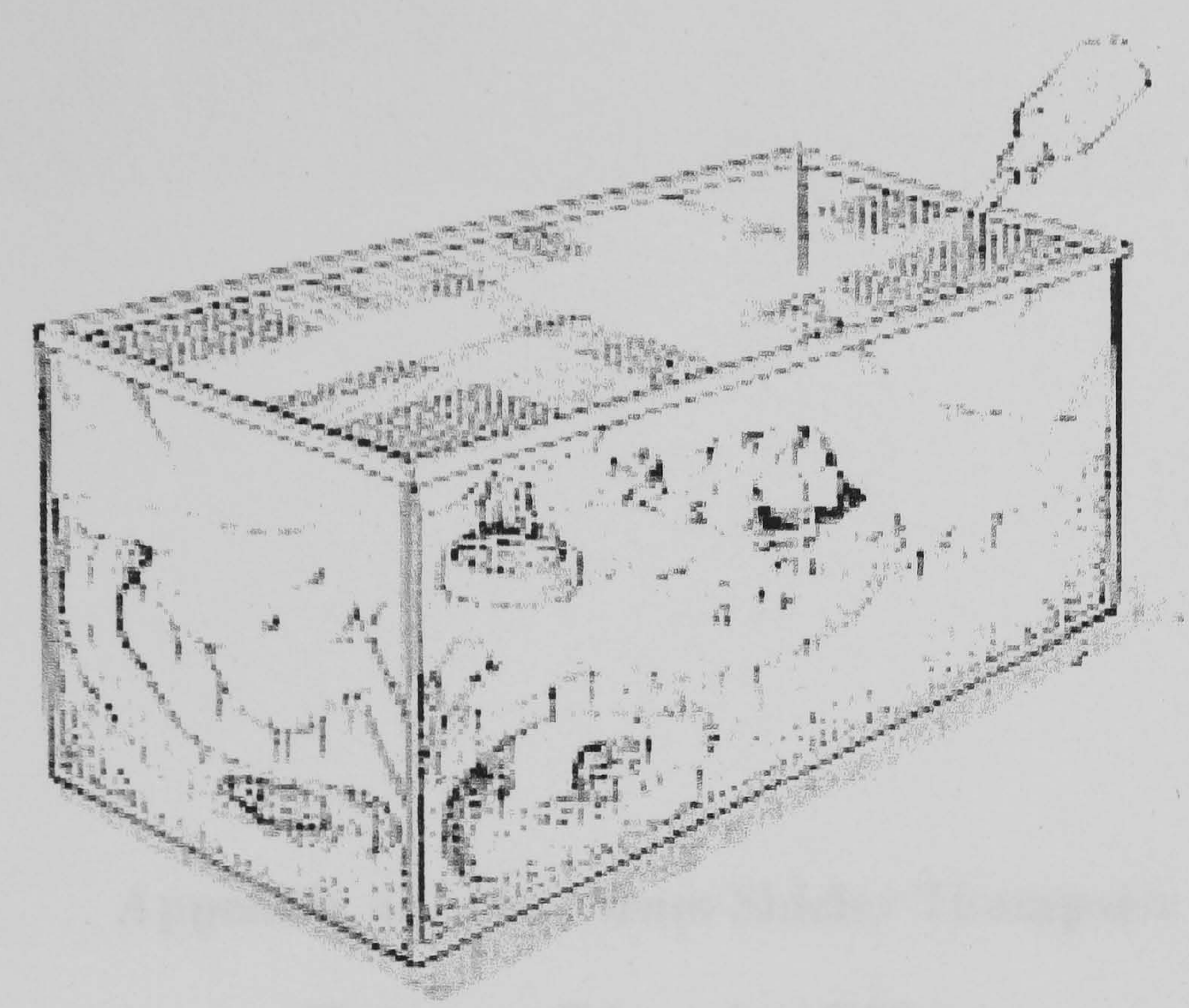
There is plenty of room

for an exercise wheel.

It is very expensive.

A home for gerbils

Home 3



This home is made from an old aquarium.

It is a cheap home.

It has a layer of garden peat, sand and gravel.

There are two rocks and a top layer of wood shavings.

There is room for twigs and hay.

Appendix 4: Letter from Shirley Thompson

Honorary Education Officer

The Bat Conservation Trust

The Bat Conservation Trust

15 Cloisters House
8 Battersea Park Road
London SW8 4BG

Tel: 0171 627 2629
Fax:0171 627 2628

email: enquiries@bats.org.uk
Web site: http://www.bats.org.uk

SHIRLEY THOMPSON
[redacted]

20 March 1999

Dear Jane,

Thank you for your letter. I was very interested to read about the subject of your PhD and would like to hear the results of your studies (the bat bit) at some time if you are able to find the time.

I have looked through the bat facts, and am impressed that you have taken the trouble to check them with BCT. So often people take as gospel everything they see in print, even PhD students! The only one really wrong is to say FALSE to *'bats are endangered*, but I get the impression that this was a mistake on their part anyway. However, I have suggested alternative wording on several, as I think they could be improved. Also enclosed is a copy of the *Watch Battitudes Quiz*, and some of BCT's own material in case you want to include some different facts. I feel Satis overplayed the legal aspect for children.

As you are a member of BCT I hope you won't mind me asking that when talking with children you suggest they write for their own free information bat pack from the BCT office.

All the very best with your studies. Don't hesitate to contact me again if I can help in any way.

Yours sincerely

Shirley Thompson

Shirley Thompson
Hon. Education Officer

Appendix 5: Information used for the Bats in the main study

The children had to decide what to do about some bats in the roof of a library. Then they had to read these cards and decide whether to change their original plan.

BAT FACT?	BAT FACT?
Bats' droppings are a health hazard.	Bats can live just about anywhere.
FALSE	**FALSE**
Bats' droppings are very dry and are only made up of the skeletons of insects.	Most species of bat need special places to roost or hibernate. Bats are suffering because old barns are made into homes, hollow trees are chopped down and caves blocked up.

BAT FACT?

Bats can damage your house

FALSE

Bats' teeth are for eating insects. They are too small to damage wood, brick or electricity cables. They get into houses through holes that are already there.

BAT FACT?

All bats drink blood.

FALSE

There are only 3 species (out of nearly 1000) of bats that drink blood. These vampire bats are only found in Central and South America.

BAT FACT?

Bats carry diseases

TRUE

All animals may carry disease but bats are less likely to carry disease than cats or dogs.

BAT FACT?

Bats are dirty

FALSE

Bats wash and groom themselves to keep themselves in peak condition for flying.

BAT FACT?
Bats are only found in old buildings
FALSE
Britain's most common bat prefers modern houses.

BAT FACT?
Bats are endangered.
TRUE
The number of bats in Britain is falling very quickly. One hundred years ago there were ten times as many bats as there are today.

BAT FACT?
Bats are quite delicate animals.
TRUE
Bats' wings are easily damaged. Many are killed by chemicals used to kill insects and by some wood preservatives used in lofts.

BAT FACT?
Bats droppings can be a nuisance.
TRUE
They can make a mess on cars, windows and things stored in lofts. But the droppings are only made of insect skeletons and crumble to a powder.

BAT FACT?

It is against the law to kill a bat.

TRUE

You can be fined up to £2000 for killing or injuring a bat.

BAT FACT?

It is against the law to disturb roosting bats.

TRUE

You cannot disturb roosting bats even if they are in your own house.

BAT FACT?

Bats' urine can be a nuisance.

TRUE

Although bats only produce small amounts of urine, it can damage polished wooden surfaces. This is sometimes a problem in churches.

BAT FACT?

Once you have got bats in your house they will always be there.

FALSE

Bats do not use a roost all year round. In winter they hibernate in caves, old mines and hollow trees.

Appendix 6: Information used for the Cups Activity in the main study

The children had to choose one of these cups to take on a picnic

Names: Holly, Ashley, Jamie, Maria

Cup	Weight	What happened when the cup is hit by plasticine bob	What happened to the temperature of the water	What happened when a heavy book is put on the top of the cup
Thin Plastic	3g each	It gets knocked down easily	It rose 2 °C in 5 minutes	It gets squashed
Glass	250g each	It stayed up all the time	It rose 0 °C in 5 minutes	It stayed the same
Thick Plastic	10g each	It stayed up most of the time	It rose 1 °C in 5 minutes	It stayed the same

Appendix 7: Marble activity for main study

The children were given the following accounts of a science investigation. They also had models of the tubes. Their task was to decide down which tube the marble would roll down faster.

Account 1: Winston and Katy

Investigation:
To find out in which tube the marble goes down the fastest

What we did:
We rested the bubble wrap tube on 6 books. We started the timer and let the marble go from the very top of the tube at the same time.

When it reached the bottom, we stopped the timer. We wrote down the time in our chart straight away. Then we did it 2 more times exactly the same.

Then we got the glue ridged tube and put it on the same pile of books in the same place. We rolled the marble down the tube 3 times just like the bubble wrap tube.

Results:

Tube	1st time (seconds)	2nd (seconds)	3rd (seconds)
Bubble wrap	6	5	6
Glue tube	3	3	3

Our results show that the marble rolls down the glue tube fastest. The bubble wrap slows down the marble because of all the little bumps.

Account 2: Hari

Investigation:
To find out in which tube the marble goes down the fastest

What we did:
We rested the glue tube on a pile of books. I rolled the marble down the tube and Rebecca timed how long it took to get to the bottom. We did it 2 more times. Then I wrote down the times.

Rebecca went and got some more books. I put the bubble wrap tube on them. We rolled the marble down 3 times and I wrote down the times it took.

Results:

Tube	1st time (seconds)	2nd (seconds)	3rd (seconds)
Bubble wrap	3	3	4
Glue tube	5	4	4

My results show that the marble rolls down the bubble wrap tube fastest.

Account 3: Rebecca

Investigation:
To find out in which tube the marble goes down the fastest

What we did:
We put the glue tube on a pile of books. Hari rolled the marble down the tube and I timed how long it took to get to the bottom. We did it 2 more times. Hari wrote down the times.

Then I got some more books from Winston and I put the bubble wrap tube on them. We rolled the marble down the tube 3 times and timed how long they took.

Hari wrote down times and I copied them later.

Results:

Tube	1st time (seconds)	2nd (seconds)	3rd (seconds)
Bubble wrap	3	3	4
Glue tube	5	4	4

The marble rolls down the glue tube fastest.

Appendix 8: Predicted SATs grades for the children

	KS 2 English	KS 2 Mathematics	KS 2 Science
St Anne's Group 1			
Alicia	4	4	**3**
Daniel	4	4	**4**
Heidi	4	4	**4**
Junior	3	3	**3**
St Anne's Group 2			
Luke	4	4	**4**
Naveed	3	3	**3**
Osei	4	4	**4**
Sheerah	4	4	**4**
Castle Hill Group			
Alex	Data not made available		**6**
Cicely	Data not made available		**6**
Joanne	Data not made available		**5/6**
Simon	Data not made available		**6**
Woodstreet Junior Group 1			
Amy	3	3/4	**4**
Che	3	4	**4**
Jillese	2	2	**3**
Patrick	3	3	**4**
Woodstreet Junior Group 2			
Chantal	3	3	**3**
Elijah	3	3	**3**
Jason	3	4	**4**
Sharon	3	3	**3/4**

Appendix 9: E1 Evidence for the four activities

1. Gerbil Homes

Evidence is taken from the text and pictures (See Appendix 3)

Home 1
- This is a home for made for hamsters
- Is made of plastic
- Is big enough for one gerbil
- There is an exercise wheel and a bowl
- It is quite expensive

Home 2
- This home is made of plastic
- It has lots of tubes connecting the cylinders
- You can make it bigger by adding more cylinders
- There is plenty of room for an exercise wheel
- It is very expensive
- Ot has four different levels (shown in picture)

Home 3
- This is a home made from an old aquarium
- It is a cheap home
- It has layers of garden peat, sand and gravel
- There are two rocks and a top layer of wood shavings
- There is room for twigs and hay
- There are three gerbils in the home (shown in picture)
- There are burrows in the home (shown in picture)

Total: 18

2. Bats

There are 14 *BAT FACT?* Cards. (See Appendix 5.)

Total: 14

3. Cups

Evidence is taken for the table of results of an investigation (see Appendix 6)
For each of the three cups there is data on:

- Weight
- What happened when the cup was hit by a plasticine bob
- What happened to the temperature of the water when it was left for five minutes
- What happened when heavy books were placed on top of the cup

Total: 12

4. Marbles

Evidence is taken from the text and results of the reports of an investigation (see Appendix 7)
There are three reports.

1. Hari

- We rested the glue tube on a pile of books
- Readings for the bubble wrap tube: 3, 3, 4 seconds
- Readings for the glue wrap tube: 5, 5, 4 seconds
- My results show that the marble rolls down the bubble wrap tube fastest

2. Rebecca

- Then I got some more books from Winston and I put the bubble wrap tube on them
- Readings for the bubble wrap tube: 3, 3, 4 seconds
- Readings for the glue wrap tube: 5, 5, 4 seconds
- Hari wrote down the times and I copied them later
- The marble rolls down the glue tube fastest

3. Winston and Katy

- We rested the bubble wrap tube on 6 books
- The we got the glue ridged tube and put it on the same pile of books in the same place
- Then we did it 2 more times exactly the same
- Readings for the bubble wrap tube: 6,5,6 seconds
- Readings for the glue wrap tube: 3,3,3 seconds
- Our results show that the marble rolls down the glue tube fastest
- The bubble wrap slows down the marble because of all the little bumps

Total: 16

Appendix 10: E1 Evidence reviewed by the groups in the Gerbils

	Home 1					Home 2						Home 3							Total
E1 Evidence	**a** is for hamsters	**b** is plastic	**c** has 1 gerbil	**d** wheel & a bowl	**e** quite expen-sive	**a** is plastic	**b** has tubes	**c** can make bigger	**d** plenty of room	**e** very expen-sive	**f** has levels	**a** old aqur-ium	**b** is cheap	**c** layers of peat	**d** rock& shav-ings	**e** twigs & hay	**f** has 3 gerbils	**g** has burrows	**18**
St Anne's Group 1				√	√		√	√	√	√			√						**7**
St Anne's Group 2		√		√		√			√										**4**
Castle Hill Group	√	√	√	√	√			√	√	√	√	√	√	√		√		√	**14**
Woodstreet Group 1		√		√		√	√	√	√	√	√	√			√				**10**
Woodstreet Group 2				√		√	√												**3**

Appendix 10: E1 Evidence reviewed by the groups in the Bats

BAT FACT? Card number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total
St Anne's Group 1	√		√	√	√	√	√		√	√	√	√	√	√	12
St Anne's Group 2	√		√	√			√	√	√		√	√	√	√	10
Castle Hill Group		√	√		√	√		√	√	√	√	√	√	√	11
Woodstreet Group 1	√	√	√	√	√	√	√		√	√	√	√	√	√	13
Woodstreet Group 2	√		√	√		√	√		√	√	√	√	√	√	11

Appendix 10: E1 Evidence reviewed by the groups in the Cups

	Thin plastic cup				Thick plastic cup				Glass cup				Total
E1 evidence	weight	stability	insulation	Strength	weight	stability	insulation	strength	weight	stability	insulation	strength	
St Anne's Group 1				√	√				√	√		√	5
St Anne's Group 2		√	√	√	√	√	√	√	√	√	√	√	11
Castle Hill Group	√	√	√	√	√	√	√		√			√	9
Woodstreet Group 1				√									1
Woodstreet Group 2	√			√	√			√					4

Appendix 10: E1 Evidence reviewed by the groups in the Marbles

	Hari's report				Rebecca's report					Winston and Katy's report							Total
E1 evidence in reports	Pile of books	BW 3,3,4	GT 5,5,4	BW is faster	More boos	BW 3,3,4	GT 5,5,4	Copied Hari's	GT is faster	Got 6 books	Same pile of books	Exactly the same method	BW 6,5,6	GT 3,3,3	GT is faster	BW bumps to slow down	
St Anne's Group 1		√	√	√	√				√							√	6
St Anne's Group 2		√		√					√				√	√			5
Castle Hill Group	√			√	√	√	√		√	√	√		√	√	√	√	12
Woodstreet Group 1			√	√		√	√	√	√						√	√	8
Woodstreet Group 2		√	√	√		√	√		√				√	√			8

Key: BW- bubble wrap tube
GT= glue ridged tube

Numbers refer to time in seconds